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APPLICATION OF REMOTE SENSING TO SELECTED PROBLEMS WITHIN THE STATE OF CALIFORNIA

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of three campuses of the University
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APPLICATION OF REMOTE SENSING
TO SELECTED PROBLEMS WITHIN THE
STATE OF CALIFORNIA

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INTRODUCTION

Robert N. Colwell

CHAPTER 1

INTRODUCTION

Although remote sensing scientists at the University of California and elsewhere have repeatedly demonstrated, in recent years, that modern remote sensing technology is potentially very useful to resource managers, the actual acceptance and use of this technology tends to lag far behind. Consequently, a primary goal of virtually all of the remote sensing-related research that is being conducted in California at the present time is that of gaining the acceptance and use of modern remote sensing technology by the managers of California's natural resources. Consistent with that goal, the overall objective of work done under this grant is to demonstrate, by means of specific case studies, that information derived from the use of modern remote sensing techniques can lead to the development and implementation of more intelligent resource management measures than would otherwise be possible. All of our case studies deal with applications that can be made of remote sensing in California, while not excluding their application, with suitable modification, in other states as well.

Those who manage the natural resources of the state of California are charged with two responsibilities that often are somewhat in conflict with each other: (1) that of producing, within the area for which they have management responsibility, the maximum amount of various goods and services (food, fiber, recreation, etc.) and (2) that of enhancing, on that same area, the quality of the environment, including its overall aesthetic appeal, and the quality of its water, atmosphere, wildlife habitat, etc. There is an increasing demand that this two-fold responsibility be fully met in California, and it is in this respect that the use of modern remote sensing technology can play a vital part.

As a first step toward the more detailed defining of the resource manager's two-fold responsibility, policy decisions usually must be arrived at relative to the uses that should be made of the natural resources in any given area. Thereafter, laws usually are made at the municipal, county, state, and federal levels that will be in consonance with those policy decisions. Next, and also in keeping with those policy decisions, resource management plans must be developed and implemented. The making of these plans requires, in turn, the acquiring of information about the resources that are to be managed -- usually in the form of resource inventories of suitably high accuracy, and made at suitably frequent intervals, so that the resource manager will know at all times, both the amount and the condition of each kind of resource that is present within each portion of the area for which he has management responsibility. As will be apparent from the studies dealt with in this report, it usually is through the use of modern remote sensing technology that the required resource-related information can best be derived.

In many cases, there is insufficient knowledge on the part of the resource managers of how remote sensing might be applied, but they have stated that, given one or more appropriate demonstrations of such applications, they would then hope to make remote sensing an integral part of their overall resource management process. From among the many possible cases fitting this description, only a few are dealt with in this progress report. These "case studies" are being performed by our remote sensing scientists on the Berkeley, Santa Barbara, and Riverside campuses, respectively, of the University of California. A description of progress made to date on these case studies will be found in Chapters 2,3, and 4, respectively, of the present Progress Report.

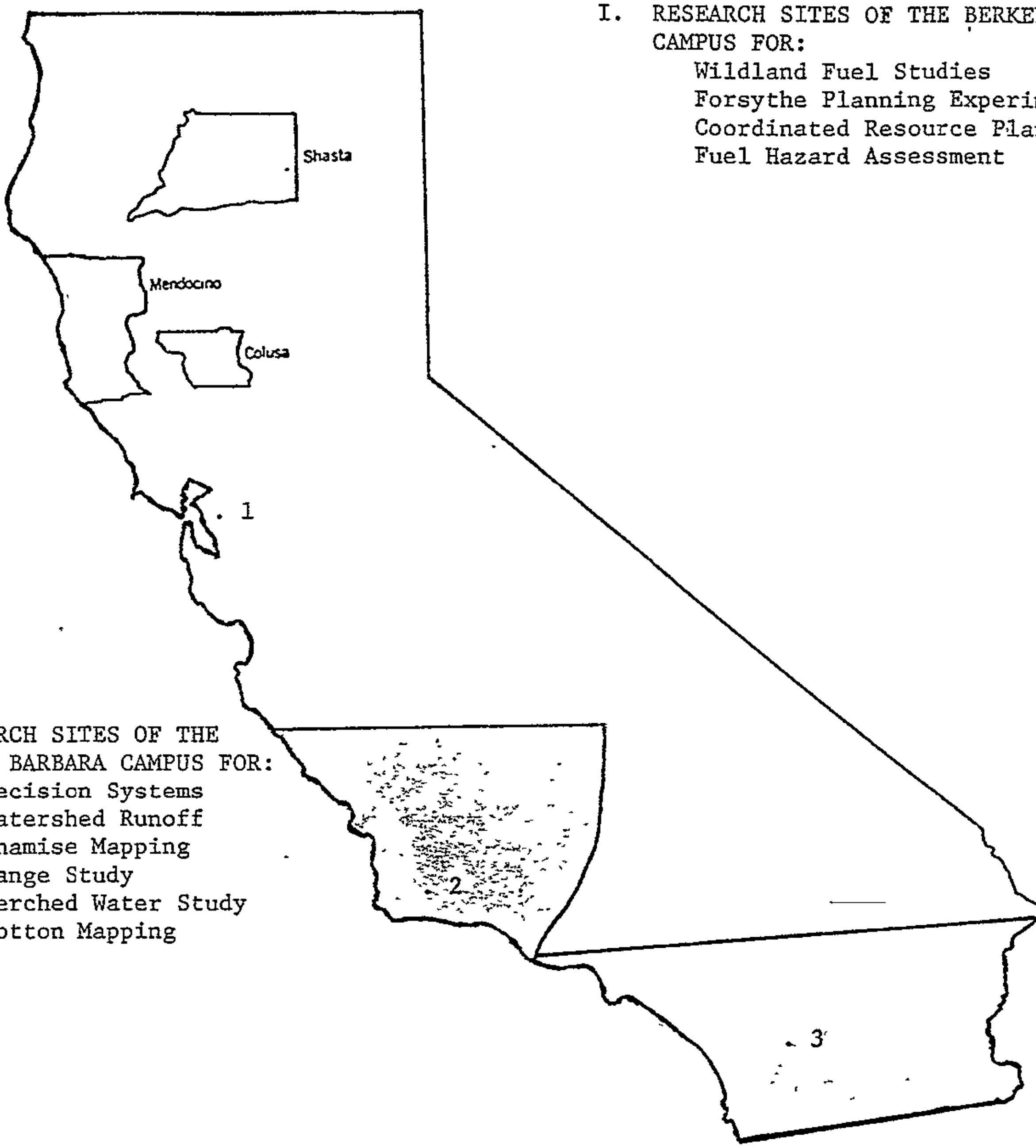
From a reading of this document it will be apparent that our integrated project entails two major but inter-related categories of activity: (1) Basic research, as necessary to develop, in each problem-oriented situation, a remote sensing-derivable classification scheme that will enable us to help the resource manager solve the particular resource inventory/management problem that is being addressed, and (2) Applied research, as necessary to ensure that the resource manager with whom we are cooperating in any given instance is in full agreement that our resource classification scheme provides him with the information that he needs in order to solve his particular resource management problem. The applied aspect of our research is further designed, in each instance, to ensure the transfer of this technology to the user. We consider ourselves to have been successful in this endeavor when the user not only understands the technology that we have helped to develop but also accepts it to the extent that henceforth he actually uses it, (instead of his previously-used methods), as the information base from which to arrive at and implement resource management decisions.

But the ultimate evidence of our success in any given instance is to be found, not merely in the user's seeming acceptance and adoption of this new technology. Rather it is to be found in his progressing rapidly toward the time when he will routinely employ that technology, entirely at his own expense, using our University scientists either not at all or, at most, merely in an advisory capacity. Even by these rigorous standards we appear to be achieving genuine success. This fact will be apparent from a reading of the campus-by-campus progress reports, (abbreviated though they are) which are included in this document.

The map of the state of California, comprising Figure 1, on the following page, has been annotated in order to indicate the specific remote sensing sites, both past and proposed, of our 3-campus project.

Because our primary goal under this NASA grant is to bring about the acceptance and adoption of modern remote sensing technology by California's resource managers, it is pertinent to highlight specific instances in which that goal is being achieved. In our recent progress reports we have provided abundant evidence (including numerous fully captioned aerial, space, and terrestrial photographs) that fuel management personnel in California are now making operational use of information which we are helping them to derive from Landsat imagery and U-2 photography. Documented in those reports is the fact that California's resource managers from several agencies are using this remote sensing-derived information operationally to determine, quite specifically, and in detail: (a) where there are dense and highly flammable brushfields that should be subjected to controlled burning; (b) where there should be mechanical removal of brush, and (c) where manual removal or chemical control of the brush must be resorted to. Also documented in those earlier reports is the fact that such determinations are being translated into action through the use of sizable amounts of manpower and equipment, specifically assigned by the resource management agencies for the purpose of implementing these decisions. In Mendocino County alone, for example, assets recently assigned for this purpose included 17 full time employees, 17 part time employees, and 2 bull-dozers, plus the necessary brushrakes, drill seeders, fertilizer and seeds to rehabilitate areas following brush removal.

I. RESEARCH SITES OF THE BERKELEY CAMPUS FOR:
- Wildland Fuel Studies
- Forsythe Planning Experiment
- Coordinated Resource Planning
- Fuel Hazard Assessment



II. RESEARCH SITES OF THE SANTA BARBARA CAMPUS FOR:
- Decision Systems
- Watershed Runoff
- Chamise Mapping
- Range Study
- Perched Water Study
- Cotton Mapping

III. RESEARCH SITES OF THE RIVERSIDE CAMPUS FOR:
- Avocado Production Studies
- Intercensal Update Studies
- Mapping Frost-Susceptible Areas

Figure 1. Map of the State of California showing general locations of study areas for remote sensing scientists of the Berkeley Campus (1); Santa Barbara Campus (2); and Riverside Campus (3) of the University of California.

In another instance, as highlighted in our May, 1979 Progress Report, a totally different aspect of applied remote sensing is featured. In this aspect, also, modern remote sensing technology is being both accepted and translated into action by the resource managers. The project entails the transplanting of wild turkeys. With respect to that project it now can be said conclusively that the following degree of acceptance and adoption of modern remote sensing technology by a user agency has been brought about through our close cooperation with personnel of the user agency, -- in this case the California Department of Fish and Game: (1) the identification (from a computer assisted analysis of Landsat digital data of a 2 million acre wildland area) of unoccupied potential habitat sites in which conditions are highly suitable for the transplanting of wild turkeys; (2) the selection of one of these areas, the "Potter Valley" site, as the one in which transplanting would first be attempted; (3) the trapping of wild turkeys of the variety most suitable for that site, based on a more detailed remote sensing-aided analysis of the site, and (4) the actual transplanting of wild turkeys in that site. Both the user agency and the U.S. Fish and Wildlife Service have indicated a desire to expand and support future phases of this program.

The following is an introductory statement regarding the material contained in the present Progress Report, chapter-by-chapter. It will be noted that the true acceptance of modern remote sensing technology by resource managers is a primary goal of all of this research. In addition to the detailing (in Chapters 2, 3 and 4) of work being done by remote sensing personnel of the 3 participating campuses, a Chapter 5 is included. That chapter summarizes approximately 50 basic remote sensing concepts that have been developed and/or tested under this NASA funded grant.

Chapter 2 of this Progess Report deals with work being conducted by personnel of the Remote Sensing Research Program (RSRP) of the Berkeley campus of the University of California. During the period covered by this report RSRP personnel have been engaged in the following 4 projects, all of which were funded jointly by NASA under this Project (No. NSG 7220) but with additional funds and related contributions being provided by various resource management agencies, as indicated:

(1) The mapping of Wildland Fuels in Mendocino County, California

The immediate objective of this research, conducted by personnel of the Remote Sensing Research Program (RSRP), University of California, Berkeley, has been to investigate the usefulness of digitally mosaicked Landsat data for mapping wildland fuel hazards in Mendocino County, California. The ultimate objective is to ensure that, based on this remote sensing-derived information, resource management decisions for the reduction of wildland fuel hazards will be arrived at and implemented.

The primary Landsat data set used to meet these objectives was centered on the 1°-by-1° Ukiah West quadrangle centered within Mendocino County, California. The quadrangle was part of the data set developed by the Jet Propulsion Laboratory and NASA-Ames Research Center for the California Department of Forestry (CDF). The data set consisted of (1) four bands of raw Landsat data from August 1976 that had been pieced together from two Lnadsat scenes, (2) one band of classified data that had been produced by applying an unsupervised clustering algorithm to the first four bands, and (3) labels applied to the resulting clusters by personnel from the CDF.

Based on the successful results of this study, as detailed in Chapter 2, these data are going to be used next year in an attempt to quantify the fuel hazards in eastern Mendocino County. Given this information, fuel management personnel will be able to carry out fuel modification actions more effectively.

(2) <u>The Forsythe Planning Experiment in Mendocino County, California</u>

The Forsythe Planning Experiment (FPE) is a demonstration project designed to explore the uses of Landsat satellite data as a general planning tool in Mendocino County, California (see Figure 1). This work is sponsored, in part, by NASA Grant NSG 7220 to the Remote Sensing Research Program (RSRP) of the University of California, Berkeley. The purpose of the project is three-fold:

1. To acquaint Mendocino County planners, resource managers and the general public with the advantages, limitations, and potential uses of Landsat satellite data and Landsat derived map products.
2. To demonstrate the feasibility of combining Landsat satellite digital data with other resource data within a computer based Geographic Information System and through this demonstration provide a time-and money-saving planning tool.
3. To develop specific output products for use in Mendocino County's General Plan update, re-zoning and land use permit processes.

To accomplish these purposes two geographic information systems are being utilized: (1) the interactive graphic display facility at the Remote Sensing Research Program, Space Sciences Laboratory, U.C. Berkeley, and (2) the Landpak Resource Information and Mapping System provided by the Berkeley office of Earth Satellite Corporation. Each system, with its respective capabilities and data requirements, is being studied to determine the optimum information handling hardware configurations and software support needed in helping to satisfy various resource information needs in Mendocino County.

Three study areas have been selected for testing these systems (see Figure 2). The study areas are located between the major population centers of Ukiah and Willits along Highway 101. The most predominant land feature is Forsythe Creek which comprises the northernmost headwaters of the Russian River. Thus, the project has been named the Forsythe Planning Experiment. Details with respect to our accomplishments to date on this experiment are provided in Chapter 2 of this Progress Report.

(3) <u>Application of California's Statewide Landsat Data Set to Coordinated Resource Planning in Colusa County, California</u>

This report describes the application of satellite-derived information to Coordinated Resource Planning in Colusa County, northern California.

> Coordinated Resource Planning is the term applied to certain cooperative efforts of land owners and public agencies in order to improve the management of the land and its resources in a given geographic area.

Personnel from the Remote Sensing Research Program (RSRP), University of California, Berkeley, have been working closely with personnel from the Stonyford Resource Conservation District in order to apply this information to the following management goals:

1. acquaint the members of the Stonyford Resource Conservation District with the potential uses of satellite-derived information as input to the Coordinated Resource Plan for the Grapevine area;
2. explore the feasibility of a satellite-based information system for this relatively small area (43,000 acres);
3. develop a methodology whereby general vegetation classes of primary interest could be refined to provide more detailed and meaningful classes for resource management; and
4. ensure the use of the refined satellite-derived information by resource managers in Colusa County as they formulate and implement various resource management decisions.

The primary data being used to meet these goals are portions of a state-wide digital Landsat data set developed for the California Department of Forestry which includes both raw and classified digital data. Secondary data sets include small-scale aerial photography and digital terrain data.

Results of this study to date appear in Section 3 of Chapter 2 of this Progress Report.

(4) Wildland Fuel Hazard Assessment in Shasta County, California

This work is being performed in close cooperation with personnel of the Shasta County Fuel Break Planning Committee, a group which seeks to develop and implement aggressive brush land management in eastern Shasta County. The expected benefits of such a program would be to reduce fuel loading, increase water yield, increase livestock production, improve wildland habitat, increase forest productivity, reduce soil erosion, reduce air pollution, and improve esthetic values. Initially, the primary objective of the involvement of our RSRP personnel with the Shasta County Vegetation Management Project (VMP) is to provide a wildland fuel map which can be integrated with other forms of auxiliary data (particularly data pertaining to property ownership). The resulting data set will be used to assist in the development and implementation of fuel management plans in Shasta County. The basic vegetation map will be derived from the statewide classified Landsat data set produced for the California Department of Forestry.

Results to date of this recently-initiated study will be found in Section 4 of Chapter 2 of this Progress Report.

Chapter 3 deals with work being conducted by personnel of the Geography Remote Sensing Unit (GRSU) of the Santa Barbara campus of the University of California. During the period covered by this report GRSU personnel have been engaged in the following 5 projects, all of which were funded jointly by NASA (primarily under this Project No. NSG 7220) but with additional funds and related contributions being provided by user agencies, (i.e. by resource management agencies), as indicated:

(1) Study of the Remote Sensing Interface with Decision Systems

This project is being performed through cooperative relationships between the GRSU and the County of Santa Barbara. A major objective of the project is to use remote sensing-derived information as the basis for making much-needed amendments in the county's General Plan with respect to rangeland resources, and then to study the effects of such amendments on the county's rangeland economy. Park I of Chapter 3 contains the GRSU's evaluation of the present environmental information system in use by Santa Barbara County, while an Appendix to Part I examines the great potential of using Landsat-derived information in connection with that system. For specific phases of this study funding was provided by the NASA Ames Research Center. In addition, Santa Barbara County matched NASA funding to permit the assignment of certain of the county's Department of Environmental Resources (DER) personnel and also some of their Data Services personnel. Anticipated funding for the next phase of this project includes an amount of $20,000 to be provided by DER.

(2) Watershed Runoff Study

In part 2 of Chapter 3 a description is given of continuing work being performed by GRSU personnel in cooperation with the Kern County Water Agency (KCWA). That Agency continues to provide field surveys, watershed calibration computations and personnel man hours in support of this project. KCWA will continue this cooperation in the coming year through such activities as cluster labeling, field checking, error analysis, and model calibration for remote sensing-derived inputs. One objective is to continue to gain steadily increasing acceptance of modern remote sensing technology by KCWA personnel through their utilization, (as integral parts of a new information system), of hardware and software developed by our GRSU scientists. Such a system should permit the making of far more timely and accurate runoff estimations than are presently possible. As a corollary, there is a second objective, namely that of ensuring that KCWA personnel will continue to implement in the field various management decisions (.e.g. the construction of dams and other structures for the control of watershed runoff) as a result of information derived through the use of this technology. An analysis of the image processing techniques and runoff estimation procedures that are being implemented in this research is providing results that will constitute the Master's thesis for the GRSU leader of this project.

(3) Chamise Mapping

This project seeks to use Landsat-derived information about chamise brushfields as a means of developing and implementing improved brushfield management measures. The project is being conducted with close cooperation of the U. S. Forest Service personnel of the Los Padres National Forest (LPNF). All vegetation history and siting data with respect to chamise brushfields on the LPNF come from records held by the U.S. Forest Service. That agency also has established the parameters of this project by carefully defining its needs for information about chamise fuels (e.g. age classes, density classes, slope classes). Additional support of the project has come in the form of two undergraduate student internships. These interns are expanding the fire history map to include all of Santa Barbara County. They also are investigating the annual phenology of chamise chaparral and its response to disruption by fire and man, all with a view to developing and implementing better brushfield management and measures. Results being achieved from this research are serving as the basis for a Master's thesis that soon will be completed, dealing with the use of Landsat data to monitor seasonal changes in chamise moisture content -- a critical parameter in relation to the flammability, and hence the fire hazard, of chamise brushfields.

(4) Range Management Study

This project seeks to use remote sensing as a means of providing information needed in deciding questions such as the following: Within areas of Santa Barbara County that presently are zoned for agriculture, what portions might advantageously undergo changes in land use in the direction of more intensive multiple uses? What would be the consequent reduction in range carrying capacity and how adverse would the effect be on the local rangeland economy? At present investigations are being concentrated in a pilot study area known as the "Bixby Ranch Development", which is in the Point Conception area of the Santa Barbara County coast. The work is being supported to a significant degree by the Santa Barbara County Department of Environmental Resources.

(5) Cotton Mapping from Landsat Imagery

This research project seeks to provide a much improved means for the mapping of cotton fields in California's San Joaquin Valley in support of the joint state and federal Pink Bollworm Control Program. During the course of this project it has received generous supplemental funding by the NASA Ames Research Center and the California Department of Food and Agriculture. A critical element in the control of pink bollworm depradations to cotton crops is that of achieving effective "plowdown" of all cotton fields during the winter months so that there is inadequate material left on the soil surface for the over-wintering of these insects. Results to date indicate that the mapping and monitoring of all cottonfields, in a manner that will ensure that all such fields are subjected to timely "plowdown", is better achieved through the analysis of Landsat MSS data than by any other means.

Details with respect to all of the above mentioned activities of the GRSU on the U.C. Santa Barbara campus will be found in Chapter 3 of this Progress Report.

Chapter 4 deals with work that is being performed by personnel of the Remote Sensing Unit on the Riverside campus of the University of California. Most of the work performed during the past year by that Unit has been in close cooperation with the California Avocado Commission and the University of California's Agricultural Experiment Station in an effort to develop more effective means for the inventory and monitoring of Southern California's avocado crop, thereby permitting that crop to be managed more intelligently. Improved management of that crop is vitally needed at the present time in view of the great rapidity with which avocado crop acreage is expanding, year-by-year.

The unprecedented increase in avocado acreage in California during the past eight years has created a nearly impossible crop forecasting problem for the California Avocado Commission. Specifically, acreage has increased from less than 26,000 acres in 1972 to more than 55,000 acres in 1980. No agency has been able to keep an accurate and timely inventory of California's avocado cropland during this period. The hilly terrain, sparse road net and prohibition of travel from field to field (to prevent transmission of root rot disease) have made inventories by conventional methods most difficult and in some areas nearly impossible. The California Avocado Commission and the University of California Agricultural Experiment Station are matching funds with NASA (in the amounts of $45,000 and $20,000, respectively, during the present year) so that, working in close cooperation with our Remote Sensing Unit on the Riverside campus, they can address the following two important aspects of the problem: (1) The California Avocado Commission's need for accurate production estimates; and (2) the development of a workable methodological, remote sensing-based approach to the creation of an Avocado Production Potential Information System, (APPIS). Given such information, year after year, the Commission could better balance supply and demand with respect to agricultureal production; they also could take a longer term view and decide what specific steps should be taken, and with what degree of rigor, as the Commission seeks to fulfill its responsibility of controlling the production and marketing of California's avocados.

The specific objective of the APPIS portion of the study is to develop an Avocado Production Information System that can be updated annually at a minimum of effort and cost. While the use of Landsat imagery is proving to be quite useful in monitoring changes, and especially in locating areas in which new acreage is being developed for avocado production, a multi-stage approach is proving to be necessary, -- one which will effectively use high altitude (U-2) photography. Such a need can be appreciated once an awareness of the small parcel size is gained. For example, in San Diego County the average parcel size is less than 5 acres and producing parcels of less than one-half acre have been discovered.

Because of the great number of small parcels in San Diego County our study is showing the necessity of using imagery with sufficient ground resolution to detect the existence of avocado trees (as opposed to citrus or ornamental trees) on the small parcels. Once these small parcels have been identified as possessing avocados, it should not be necessary to perform a close inspection of them for at least another five years. In the intervening years a cursory inspection with small-scale imagery can be performed to verify the continued existence of the trees.

In the West Mesa area of Rancho California, which is in southwestern Riverside County, the parcels average approximately 20 acres each. The 10,000 acres either planted or being prepared for planting are almost exclusively for the production of avocados. Therefore, the imagery scale and associated spatial resolution, will normally not need to be any greater than that obtainable from high-altitude platforms such as the U-2. Our studies to date indicate that, with the recently improved image processing of Landsat data, it will be possible to monitor an area like Rancho California from such data in the intercensal years.

With respect to the most suitable type of photographic film for use in larger scale aerial photography, our studies have shown during the past year that Kodak Aerial Ektagraphic (2448) natural color film is more useful in detecting avocado trees than is Color Infrared film.

Areas newly cleared for planting, such as those in Rancho California, are highly interpretable on U-2 photography, thereby facilitating confirmation of Landsat-derived information. Future clearing can be monitored by comparison of subsequent LANDSAT scenes with archived U-2 photography. Such transitions in land use have important implications not only for estimating future avocado production; in addition water demand assessments, requirements for fire protection, and changes in predicted tax revenues are important categories affected by such changes. The actual delimitation of tree-crop areas and cleared zones, the determination of relative age, and the assessment of the area-by-area potential of lands for avocado production are more successfully accomplished with U-2 photography than with LANDSAT imagery. The limited availability and coverage of U-2 photography, however, makes the preliminary evaluation of LANDSAT data highly desirable, at least as a first step. In contrast, the ready availability of complete LANDSAT coverage is an important consideration governing its use for inventory update. When it is available, U-2 imagery may also be effectively employed in the update process.

An additional effort that currently is being made by our Riverside Remote Sensing Group with respect to Southern California's avocado industry entails the use of high altitude thermal infrared imagery for the detection of frost-prone areas. Frost frequency and severity are key factors in the successful production of avocados and other semitropical and tropical crops. At present, the available information on frost susceptibility within small geographical areas is grossly inadequate. The application of such information, even where it currently is available, is similarly limited. Better information with respect to the local distribution of frost susceptible areas could serve two purposes: (1) it would permit the delineation of various classes of frost hazard, thereby allowing the grower to avoid high-risk areas or to select particularly frost-resistant varieties for planting in such areas, and (2) it would provide much of the information needed in delimiting areas of economic avocado production potential. Maintenance of the avocado production inventory would be easier if only those areas known to be capable of commercial production had to be monitored. The present network of climatic stations is much too sparse to supply frost susceptibility information at the desired level of detail. A primary purpose of the U-2 thermal infrared mission that was flown of southern California areas by NASA in January of this year was to fill this gap. As the overflight was taking place, personnel of the Remote Sensing Group of the Riverside campus were making ground measurements at designated sites within the study area of San Diego County. To date only a cursory examination of this recently-received imagery has been possible, but that examination leaves us greatly encouraged. For example, the dendritic pattern resulting from cold air drainage down water-courses can clearly be seen on this imagery by reason of its darker tone on the positive thermal infrared prints. Since many new avocado groves are planted on valley slopes, the actual depths of the inversions created by cold air drainage are potentially of considerable significance in assessing the frost hazards at various slope locations. The plateaus appear to be warmer than their flanks in the image, but even within plateaus there is some variation of potentially great significance. Mapping of the geometrically corrected, calibrated digital data will permit the identification of particular geographic locations having specific temperature values. It is anticipated that, given this capability, we then will be able to locate and map various frost hazard categories. We anticipate that the presentation of well documented findings of this type, based on our correlation of this recently-received thermal infrared imagery to the "ground truth" thermal data which we collected simultaneously in the field, will constitute a major and highly significant portion of our next progress report.

Details with respect to all of the items mentioned above will be found in Chapter 4 of this report.

In Chapter 5 of this Progress Report a significant amplification is given of material that was included in Chapter 5 of our 1979 Progress Report. It deals with "Basic Considerations Involved in Remote Sensing" and is included here for two reasons:

(1) This treatise, as prepared by the present project's principal investigator, is a direct outgrowth of work which our NASA-funded, multi-campus group has performed during the past decade under two projects: (a) the present one entitled "Applications of Remote Sensing to Selected Problems within the State of California" and (b) its predecessor entitled "An Integrated Study of Earth Resources in the State of California Using Remote Sensing Techniques" which was similarly NASA-funded;

(2) Based on the highly abbreviated version which, as previously mentioned, appeared in one of our earlier progress reports, the Principal Investigator was invited to expand upon this material and to present it as the opening or "keynote" address at a very significant international meeting that was to be held at the University of Idaho in September, 1979. That meeting, sponsored jointly by the Commission on Photographic Interpretation of the International Society of Photogrammetry and the International Union of Forestry Research Organizations (IUFRO) was, indeed, held and the keynote paper, part of

which is embodied in Chapter 5 of this Progress Report was acclaimed as having set the stage in a truly admirable fashion for the ensuing week-long series of technical remote sensing-related papers. In fact, it was asserted at the meeting, that greater acceptance of modern remote sensing technology by resource managers both in the United States and internationally, should surely result from an increased appreciation of these "concepts", as presented at that meeting, and as reproduced (in abbreviated form) in Chapter 5 of this Progress Report. Herein would seem to lie one of the greatest potential benefits of the work which we have been performing under NASA funding of this applications-oriented multi-campus project.

Appendix A, at the conclusion of this report consists of an itemized updating of information pertaining to this NASA grant as requested by the Manager of NASA's University Application Program. Items appearing in that Appendix are as specified under that Program.

CHAPTER 2

NORTHERN CALIFORNIA STUDIES

CHAPTER 2

NORTHERN CALIFORNIA STUDIES

INTRODUCTION

Throughout the past year, personnel from the Remote Sensing Research Program (RSRP), University of California, Berkeley, have been working closely with personnel from wildland management and county planning agencies in northern California. The objective of this research has been to demonstrate the proper integration of remote sensing and ancillary data to meet the information needs of those who manage natural resources. Only after these information needs have been met can the land managers develop and implement plans for the wise use of all wildlands and associated natural resources under their jurisdiction.

The key to our success in conducting this research has been the active participation of the land managers themselves in the analysis of the remote sensing and ancillary data. Because of this participation we are finding that the field personnel are not only acknowledging but are also making extensive use of the fact that these remotely-sensed data can fulfill and/or supplement many of their information needs in a cost-effective manner, thereby enabling them to make and implement resources management decisions more intelligently than would otherwise be possible.

The following sections document the work being conducted in Mendocino, Colusa and Shasta Counties, California (see Figure 1), through the

Figure 1. Location of Mendocino, Colusa and Shasta Counties in northern California. Investigations are being conducted here by personnel of the Remote Sensing Research Program, University of California, Berkeley, to demonstrate the usefulness of remote sensing-derived information for planning and implementing wildland management programs in selected sites within these counties.

cooperative efforts of resource managers and personnel of our Remote Sensing Research Program (RSRP). Part I describes the application of a state-wide Landsat data set to the fuel mapping requirements of Mendocino County, California. While this section, like the others, was primarily funded by our NASA Grant 7220, it builds upon research that was cooperatively funded, during an earlier period, by NASA Grant NCA-2-OR050-903. Part II describes the first computer-assisted application of Landsat data and ancillary data for general planning in Mendocino County, California. Part III describes the applications of Landsat and ancillary data for coordinated resource planning within the Stonyford Resource Conservation District, Colusa County, California. A major portion of the funding for this research has been provided by the Office of the Governor, State of California, through Cal Space contract CSG/CS36-79. The results will be used to meet, in part, the academic requirements for Louisa H. Beck to complete her Master's degree in Environmental Planning from the University of California. Finally, Part IV describes preliminary investigations for the application of the State-wide Landsat data set to assess the hazardous build-up of fuels in wildland areas of Shasta County. Although the major funding for Parts I and III have come from sources other than the NASA Office of University Affairs, this Office, under Grant NSG7220, has provided the seed money which made these projects possible. Consequently, these projects are being carried to a more operational conclusion than would have been possible under the original funding.

After reading these four sections, one might raise the question as to whether there is duplication among them of the research being conducted in the northern California counties. To a certain degree there is, because many of the user agencies have common information requirements. The apparent duplication, however, is, in fact, a continuous building process by which the results derived for use by one resource manager, and in one area, are then modified and applied by another resource manager in another area. For example, the wildland vegetation on the relatively continuous, unbroken topography which is present in Mendocino County can be mapped quite effectively through the use of the State-wide Landsat data set (see Part I). On the other hand, the resolution of this data set is not sufficient to meet the information requirements in areas of heavily dissected topography such as those present in the Colusa County study area. Therefore, only through developing a second application and modification of the remote sensing technology are we able to assist a second wildland manager in developing an information system which he will use on an operational basis in obtaining the needed information, making resource management decisions based on the remote sensing-derived information, and implementing various resource management measures, based on those decisions.

PART I

APPLICATION OF DIGITALLY MOSAICKED LANDSAT DATA TO MAPPING WILDLAND FUELS IN MENDOCINO COUNTY, CALIFORNIA

by

Andrew S. Benson

and

Louisa H. Beck

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PROJECT SUMMARY

The immediate objective of this research, conducted by personnel of the Remote Sensing Research Program (RSRP), University of California, Berkeley, has been to investigate the usefulness of digitally mosaicked Landsat data for mapping wildland fuel hazards in Mendocino County, California. The ultimate objective is to ensure that, based on this remote sensing-derived information, resource management decisions for the reduction of wildland fuel hazards will be arrived at and implemented.

The primary Landsat data set used to meet these objectives was centered on the 1°-by-1° Ukiah West quadrangle centered within Mendocino County, California. The quadrangle was part of the data set developed by the Jet Propulsion Laboratory and NASA-Ames Research Center for the California Department of Forestry (CDF). The data set consisted of (1) four bands of raw Landsat data from August 1976 that had been pieced together from two Landsat scenes, (2) one band of classified data that had been produced by applying an unsupervised clustering algorithm to the first four bands, and (3) labels applied to the resulting clusters by personnel from the CDF.

The cluster labels applied to the classified data were too general to be of any use for fuel management planning. Therefore, the clusters were relabeled by personnel of the RSRP and fuel management specialists from Mendocino County into appropriate fuel management classes and National Fire Danger Rating System classes.

A highly useful fire behavior map based on National Fire Behavior Rating System models has been completed for the Ukiah West quadrangle for about .2¢ per acre. In addition, a four-class brush map (chamise, manzanita, chaparral, and "other") has been completed for an intensive study area in the northeastern quarter of the county along with the relevant tabular information. These products have been given to fuel management personnel in the area for evaluation.

Based on the successful results of this study, these data are going to be used next year in an attempt to quantify the fuel hazards in eastern Mendocino County. Based on this information, fuel management personnel will be able to carry out fuel modification actions more effectively.

1.0 Introduction

1.1 Historical Perspective

To date, the fuels-related remote sensing research conducted in Mendocino County by personnel of our Remote Sensing Research Program (RSRP), University of California, Berkeley, has been restricted to the eastern half of that County (see Benson and Katibah, 1978, and Benson, Beck and Henderson, 1979). It has been restricted to this area because of (1) the difficulty of piecing Landsat scenes together in order to provide digital coverage of the entire County, and (2) the expense of analyzing the digital Landsat data for the entire County without some form of land use classification scheme and associated spectral stratification. However, in 1977 the California Department of Forestry (CDF), working cooperatively with the NASA-Ames Research Center, produced a statewide, stratified, 16-class ground cover map which had been aggregated from clustered Landsat digital data. Although these ground cover labels were sufficiently detailed to meet the State's forest planning needs, they were inadequate to meet the local information needs of fire control and fuel management specialists. Consequently, fuel management specialists from Mendocino County and remote sensing specialists from the RSRP redefined the ground cover labels to meet this specific wildland information requirement. Then, each of the 113 spectral clusters developed for the Ukiah West quadrangle were relabeled to produce a fuel management map and related tabular output. This procedure of using the spectral clusters as a data base, building on the 16-class cover map that had been aggregated to meet Statewide forest information needs, has served to demonstrate the greatest strength of the Landsat-derived CDF data set. Spectral clusters can now be labeled to meet specific management information needs instead of having to either adapt other information bases or develop new ones.

1.2 Objectives

The immediate objective of this research has been to investigate the usefulness of the digitally mosaicked Landsat data set (hereafter referred to as the CDF data set) for mapping wildland fuel hazards in Mendocino County, California. The ultimate objective of this research has been to ensure that, based on this remote sensing-derived information, resource management decisions for the reduction of these wildland fuel hazards would be arrived at and implemented. To meet these objectives personnel from the RSRP worked closely with fuel specialists from the County to define meaningful fuel classes and to evaluate the output products. The output products included tabular statistics giving the areal extent of the fuel types in the County, and photographic products which graphically illustrated the distribution of these fuel types both within the study area and in relation to each other.

1.3 The Remote Sensing Data Set

The primary Landsat data set that was used to meet the objectives of this study was the 1°-by-1° Ukiah West quadrangle centered within Mendocino County, California. The quadrangle was part of the data set developed by the Jet Propulsion Laboratory (JPL), Pasadena, California, and NASA-Ames Research Center, Moffett Field, California, for the CDF.

The JPL created 1°-by-1° quadrangles of the entire State from four bands of raw Landsat data (August 1976) by piecing Landsat scenes together digitally, resampling the data to produce 80-meter-by-80-meter pixels, and registering the pixels to a Lambert Conic Conformal projection. The four bands of raw data were classified on the ILLIAC array processor at NASA-Ames using an unsupervised classification algorithm which grouped the spectral data into similar spectral clusters. To simplify the classification task, the State was divided into 32 ecozones, and the resulting classification was based on the statistics generated from each ecozone. Each spectral cluster was labeled as one of the forest classes defined by the CDF. The class definitions and the cluster labels are listed in Tables 1 and 2, respectively. The multi-band data set, therefore, consisted of the following: Band 1 -- MSS 4 (green), Band 2 -- MSS 5 (red), Band 3 -- MSS 6 (near reflectance infrared), Band 4 -- MSS 7 (far reflectance infrared), and Band 5 -- unsupervised classification of Bands 1, 2, 3, and 4.*

1.4 The Mendocino County Study Site

Mendocino County, located on the coast of northern California (see Figure 1), was an ideal area in which to carry out a remote sensing-aided wildland fuel mapping study. Virtually all of the fuel types present in northern California exist within this County. These include dense coniferous forests with heavy accumulations of litter and downed material; mature, dense fields of brush and hardwoods with high concentrations of

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*Three additional bands of hypsographic data were created from digital terrain tapes and were overlain on the spectral and classified bands. These last three bands were not used in this study, however, because up to the present time their registration inaccuracy to the first four bands has varied from 3 to 12 pixels, which is too great to be useful in our study.

Table 1. Class descriptions used by CDF personnel to label the spectral clusters from the unsupervised classification of the State-wide Landsat digital mosaic.

CLASS DESCRIPTIONS

A. Bare rock

B. Water

C. Agriculture (pattern recognition)

D. Urban (may be residential and/or commercial)

E. Alkali flats

F. Barren (predominantly bare soil, less than 5% vegetative cover)

G. Grassland - Vegetation predominantly grass. Cover greater than 5%. May be annual or perennial grasslands. Less than 10% tree cover. May include herbaceous vegetation.

H. Desert shrub - Vegetation consists of xeric shrubs, generally open with much bare soil and desert pavement exposed. However, dense stands may occur. Vegetation ranges from .5 to 3 meters tall. Less than 10% tree canopy. Generally found on flat or slightly sloping terrain.

I. Brush - Open to dense (greater than 5% ground cover) evergreen or deciduous shrubs, rarely more than 5 meters tall (usually 1-3 meters). May have herbaceous understory. Less than 10% tree canopy. This includes riparian vegetation along waterways.

J. Hardwood-woodland - Scattered hardwoods (deciduous and evergreen), 10-25% canopy closure. May have grass or brush understory.

K. Conifer-woodland - Scattered conifers, 10-25% canopy closure, often with an herbaceous or brush understory.

L. Hardwood - Greater than 25% canopy closure of hardwood species. Less than 20% conifer in the stand. May have an herbaceous or brush understory.

M. Hardwood-conifer - Greater than 25% canopy closure, with hardwoods comprising greater than 50% but less than 80% of the stand. Conifers comprise 20-50% of the stand. There may be an herbaceous or shrub understory.

N. Conifer-hardwood - Greater than 25% canopy closure, with conifer species comprising greater than 50% but less than 80% of the stand. Hardwood species comprise 20-40% of the stand. There may be an herbaceous or shrub understory.

O. Conifer - greater than 25% crown closure of conifer species. Less than 20% hardwood in the stand. There may be an herbaceous or brush understory.

Table 2. CDF class labels as applied to the 113 clusters present in the Ukiah West 1° x 1° quadrangle.

NORTH COAST INTERIOR ECOZONE		NORTH CENTRAL INTERIOR ECOZONE		NORTH CENTRAL COAST ECOZONE	
CLUSTER NUMBER	CDF CLASS	CLUSTER NUMBER	CDF CLASS	CLUSTER NUMBER	CDF CLASS
1	fill	33	fill	69	fill
2	fill	34	B	70	B
3	B	35	I	71	O
4	other	36	J	72	O
5	O	37	I	73	O
6	I	38	I	74	O
7	G	39	M	75	G
8	N	40	M	76	I
9	I	41	J	77	G
10	O	42	I	78	O
11	N	43	M	79	K
12	I	44	J	80	O
13	G	45	M	81	G
14	G	46	L	82	N
15	K	47	J	83	N
16	N	48	K	84	J
17	F	49	I	85	N
18	G	50	J	86	M
19	K	51	L	87	M
20	G	52	J	88	M
21	J	53	J	89	M
22	G	54	G	90	L
23	M	55	L	91	L
24	other	56	G	92	L
25	G	57	C	93	J
26	L	58	G	94	F
27	other	59	G	95	G
28	J	60	G	96	F
29	other	61	C	97	G
30	G	62	G	98	F
31	G	63	G	99 - 113 clouds	
32	I	64	G		
		65	G		
		66	F		

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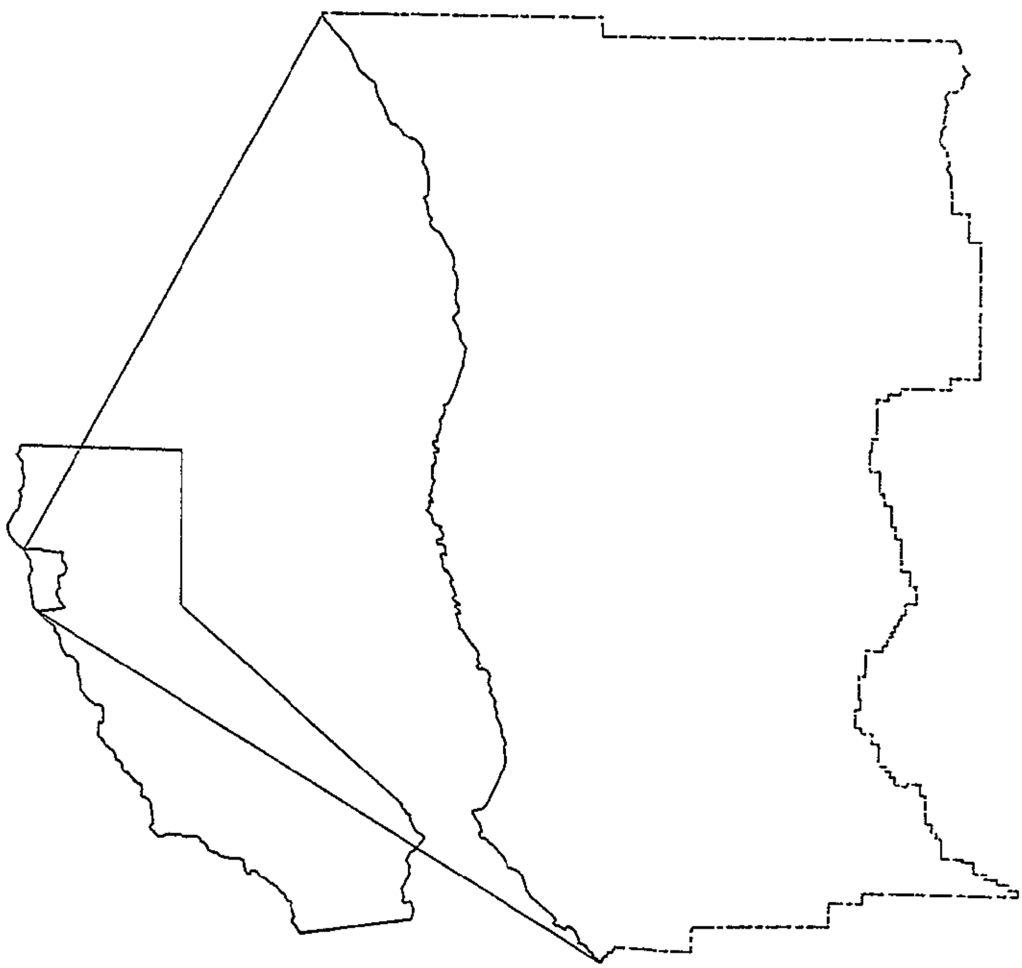

Figure 1. Location of Mendocino County in northern California.

woody fuels; and grasslands composed of fine, flashy fuels. In addition, weather patterns vary considerably in this County from the coastal zone, with its heavy marine influence, to the eastern half of the County, with its continental influence. This wide range of fuel types and weather conditions results in many and varied fuel hazards, thereby making the area a logical site for evaluating the usefulness of the CDF data set for mapping wildland fuels.

The location of the 1°-by-1° CDF data set quadrangle, with respect to Mendocino County, is shown in Figure 2. This quadrangle coincides with the western half of the USGS 1°-by-2° Ukiah map sheet, and it represents 81 percent of the County area (734,000 hectares or 1.9 million acres). To cover this area, two Landsat scenes were digitally mosaicked by JPL personnel. The area was then divided into three ecozones as defined by the CDF: North Central Coast, North Central Interior, and North Coast Interior (see Figure 2). An unsupervised classification of each ecozone was performed at NASA-Ames on the ILLIAC array processor; the resulting clusters were labeled by CDF personnel.

1.5 Definition of Wildland Fuel Classes for Mendocino County, California

Two classification systems of wildland fuels were defined for labeling the CDF spectral cluster data in Mendocino County, one based on fire behavior and the other based on fuel management. These two systems are similar in that they both combine vegetation types with slope classes. The first was designed to provide the base information for fuel modification programs. Only the vegetation component of both systems was used in the labeling procedure because the digital topographic data from the CDF data set were unusable. Both the vegetation and the topographic

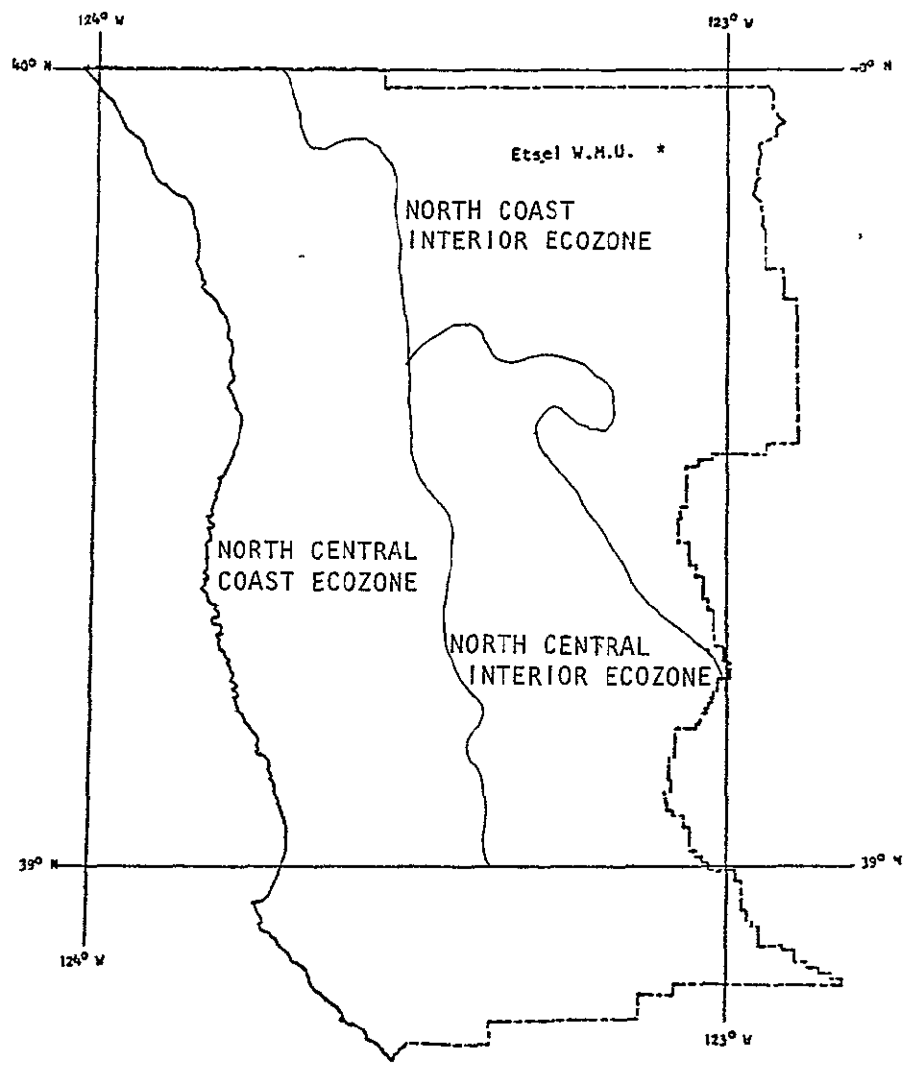

Figure 2. Location of the 1°-by-1° Ukiah West quadrangle within Mendocino County and the Etsel Watershed Management Unit which was used as an intensive study site.

components of these systems are listed in Table 3.

The fire behavior classes were extracted from the National Fire Danger Rating System (Deeming, et al., 1978). These classes included the four vegetation models that are present in Mendocino County: Model A (grassland), Model B (hardwood), Model F (brush), and Model G (conifer). These classes were to be combined with five slope classes: Class 1 (0-25 percent), Class 2 (26-40 percent), Class 3 (41-55 percent), Class 4 (56-75 percent), and Class 5 (76+ percent).

The fuel management classes were defined by Mendocino County fuel specialists. These classes included the four broad vegetation models listed above, which had been further refined into subtypes and type mixes (see Table 3). The subtypes and mixes were to be combined with four slope classes which were defined by the limitations for mechanical modification: 0-30 percent (bulldozer compaction or blade), 31-50 percent (ball and chain on highly erodible soil), 51-65 percent (ball and chain on moderately erodible soil), and 65+ percent (no mechanical modification advisable). For those areas which exceed 65 percent slope, the vegetation component would have been combined with fire behavior slope classes 4 and 5 because the recommended modification procedure would be the application of prescribed fire.

It is important to emphasize the differences between these two wildland fuel classification systems. The fire behavior classes were developed by the U.S. Forest Service as one input to a mathematical fire spread model that is used in the National Fire Danger Rating System (NFDRS). These classes are quite general because the principal objective of the NFDRS is to provide regional information for presuppression planning.

Table 3. Fire behavior models extracted from the National Fire Danger Rating System and fuel management classes defined by specialists in Mendocino County and applied to the spectral clusters of the CDF data set in the Ukiah West quadrangle.

FIRE BEHAVIOR CLASSES

(from: National Fire Danger Rating System, *1978*)

VEGETATION		SLOPE
Model A	Grasslands vegetated by annual grasses and forbs, brush and trees may be present, but are very sparse.	Class 1: 0-25 percent
Model B.	Mature, dense fields of brush 6 feet or more in height.	Class 2: 26-40 percent
Model F.	Mature chamise stands and oakbrush fields, young closed stands and mature open stands of mixed chaparral.	Class 3: 41-55 percent
		Class 4: 56-75 percent
Model G.	Dense conifer stands where there is heavy accumulation of litter and downed material.	Class 5 76 + percent

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FUEL MANAGEMENT CLASSES

VEGETATION	SLOPE
Brush (F)	0-30 percent (bulldozer)
chamise - pure *(Adenostoma fasciculatum)*	31-50 percent (ball & chain)
manzanita - pure *(Arctostaphylos sp)*	51-65 percent (ball & chain)
chaparral *(Arctostaphylos sp , ceanothus sp., Adenostoma fasciculatum)*	66 + percent (none)
chaparral/conifer	
chaparral/hardwood	
Hardwood (B)	
hardwood - pure *(Quercus sp , Arbutus Menziesii, Acer sp , Lithocarpus densiflora)*	
hardwood/brush	
hardwood/conifer	
hardwood/grass	
Softwood (G)	
conifer - pure *(Pinus sp., Sequoia sempervirens, Abies sp , Pseudotsuga Menziesii)*	
conifer/brush	
conifer/hardwood	
conifer/grass	
Grassland (A)	
grassland - pure *(Avena sp., Hordeum sp , Festuca sp., Trifolium sp , Lolium sp)*	
grassland/hardwood	
grassland/softwood	
grassland/riparian	
Other	
barren	
water	
urban	
agriculture	

Because other environmental factors, such as fuel moisture, wind, and slope, will vary considerably within the region, there is no need for the fuel classes to be any more specific. In contrast, the fuel management classes were defined by Mendocino County fuel management specialists. These classes represent the information that is needed in order to plan and implement specific fuel modification schemes throughout the County. For example, the recommended management for a brush field would be considerably different for manzanita than for chamise, although both are classified by NFDRS as Fuel Model F. Generally, in Mendocino County, manzanita grows on relatively deep soils which can be converted to permanent grassland. Chamise grows on shallow soils and the best management option may be to modify the continuous fields to a mosaic of 10-15 year age classes. This action would reduce fire hazards, although the ground cover would remain chamise.

2.0 Approach

The two-phase, stepwise procedure used to transform the spectral cluster data from the CDF data set into fire behavior and fuel management maps is diagrammed in Figures 3 and 4. The processing flow, divided into preprocessing and labeling phases, consisted of two components: the cluster labeling component and the geographic control component. The first component entailed labeling a sample of the spectral clusters by fuel classes; the second component entailed determining the geographic relationship between the CDF data set coordinates (point-line) and the ground coordinate system (UTM east - UTM north). The two components converged at the end of the labeling phase so that the areal extent of the fuel classes could be tabulated. This entire procedure was designed

Figure 3. The two-phase, stepwise procedure used to transform the spectral clusters from the CDF data set into fire behavior and fuel management maps for the Ukiah West quadrangle.

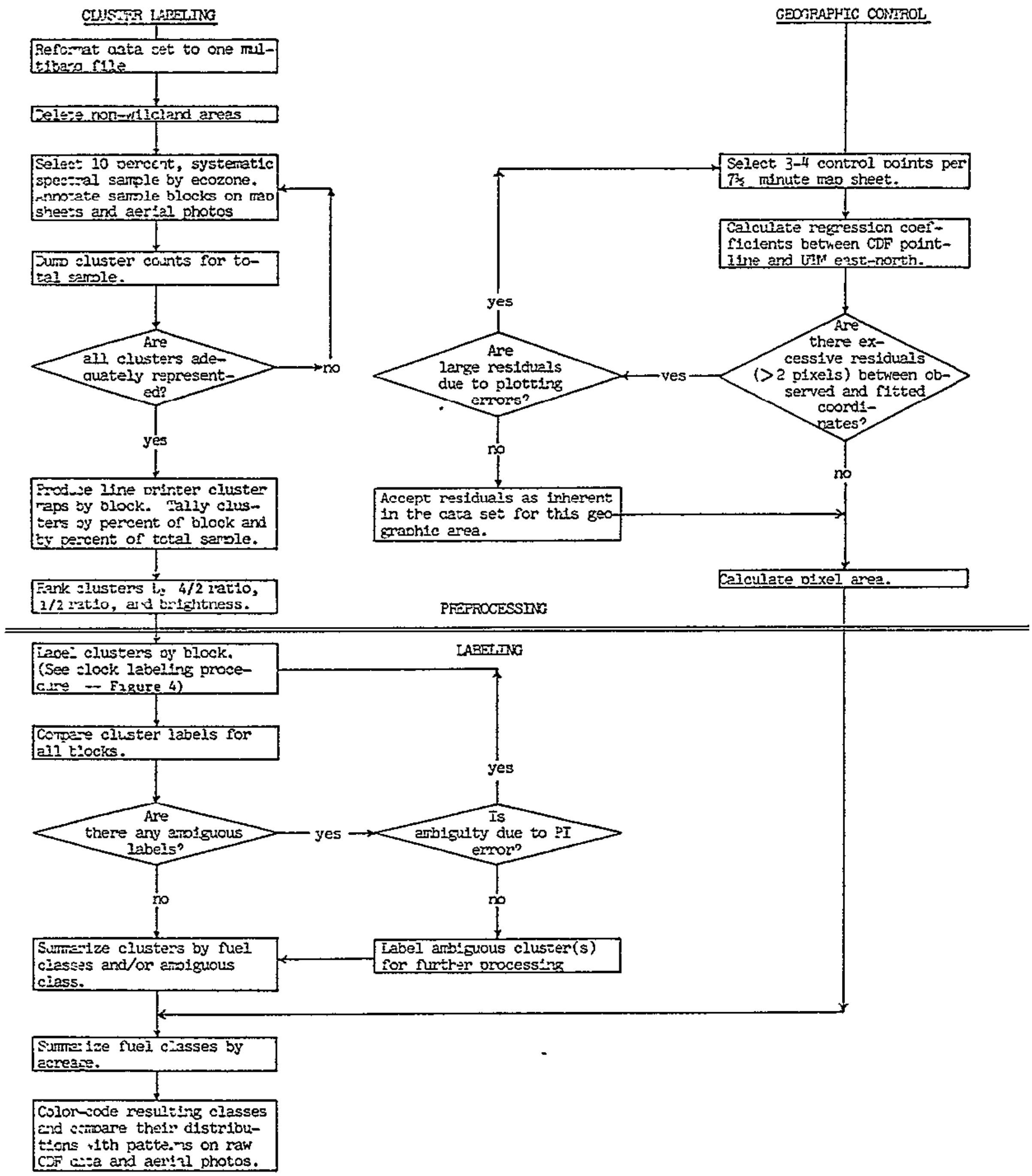
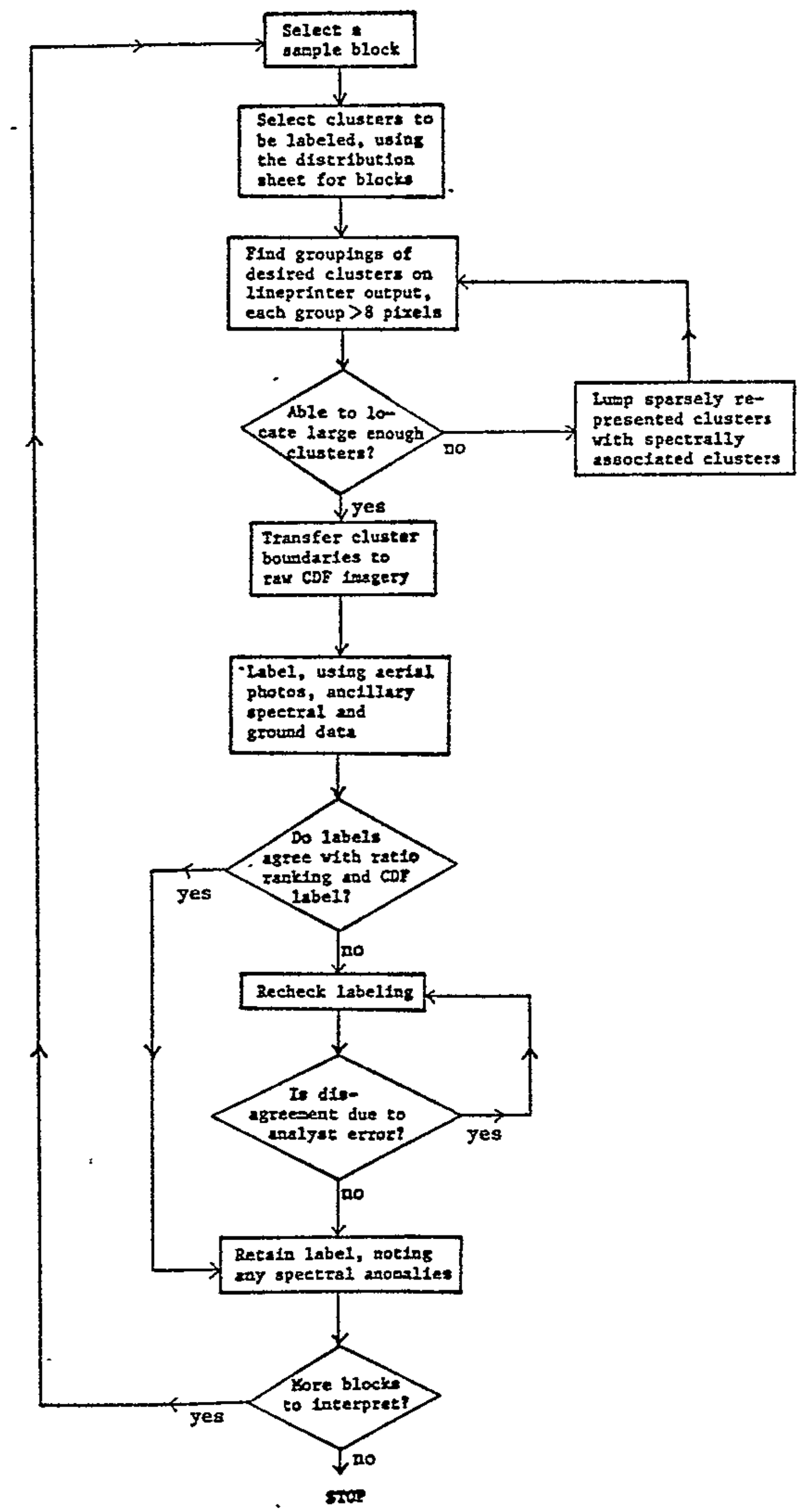


Figure 4. The cluster labeling steps within the labeling component that were used to label spectral clusters as given fuel management classes. These steps utilized the data produced and compiled in the preprocessing phase (see Figure 3) coupled with the image analysis skills of remote sensing and fuel management specialists.



such that the basic information that was produced at the end of the preprocessing phase could be applied to other wildland mapping projects. The costs associated with this phase, therefore, could be amortized over the life of the CDF data set.

A complete description of the application of the two data processing components is given in Benson and Beck, 1979, and will not be included in this report. However, one step within the cluster labeling component in Figure 3 is worthy of additional comment because it illustrates the uniqueness of the CDF data set:

Are All Clusters Adequately Represented? The ability to assess the adequacy of a spectral sample from an extensive area is unique to the CDF data set. The conventional approach to mapping wildland vegetation with Landsat digital data is to develop spectral training models for a classification algorithm by either (1) selecting the spectral models from areas of known ground conditions, or (2) sampling the spectral data from the area of interest, clustering the data into discrete spectral classes, and labeling the classes. Regardless of the approach used, however, the remote sensing specialist is never sure if he has accounted for all of the spectral variation in the area. Obviously, if this variation is not represented in the training set, the classification accuracy will be low.

In contrast, when an analyst wants to map vegetation with the digital data from the CDF set, he knows that all variation has been accounted for because the unsupervised classification algorithm has been applied to the entire study area. Therefore, he simply has to devote his efforts to selecting a sample of these clusters for the labeling procedure. He has the assurance that any classification errors will be due to mislabeling or spectral ambiguities between classes, but not due to an inadequate spectral model. For example, the initial set of sample blocks that had been selected by the RSRP analysts within the Ukiah West quadrangle was found to provide an adequate number of those clusters that were needed to map wildland resources. A number of clusters present in the quadrangle, however, were under-sampled. The analysts examined both the labels given to these clusters by CDF personnel and the locations of these clusters within the quadrangle, and determined that they represented non-wildland classes such as clouds, water, agriculture, urban and fill. If, however, any of the under-sampled clusters had been labeled as a wildland class or had fallen within a wildland area, additional blocks would have been selected until the desired sampling intensity was achieved.

3.0 Results

3.1 Output Products

The tabular and photographic outputs representing the National Fire Danger Rating System for the Ukiah West quadrangle are given in Table 4 and Figure 5, respectively. In addition, a comparison of the CDF class descriptions to the Mendocino County fuel management classes is given in Table 5. With the exception of clusters 57, and 64-68, the labels from the two classification schemes were similar. These six exceptions all included agricultural resources which could not be reliably identified based on the single date of spectral data. In all cases, however, the ambiguous agricultural clusters had been visually stratified out of the quadrangle.

Table 4. Tabular summaries of the pixel count and associated acreages for (a) the National Fire Danger Rating System classes (NFDRS) and (b) the fuel management classes present in the Ukiah West quadrangle.

UKIAH WEST QUADRANGLE

(a)
NATIONAL FIRE DANGER RATING SYSTEM

VEGETATION MODEL	PIXELS	ACRES*
F: BRUSH	141,186	231,827.4
B: HARDWOOD	268,570	440,991.9
G: CONIFER	467,180	767,109.6
A: GRASSLAND	248,877	408,656.0
WATER	1,103	1,811.1
OTHER	42,852	70,363.0
TOTAL	1,169,768	1,920,759.0

(b)
FUEL MANAGEMENT CLASSES

VEGETATIVE TYPE	PIXELS	ACRES*
CHAMISE	50,288	82,572.9
CHAPARRAL	77,959	128,008.7
MANZANITA	12.939	21,245.8
HARDWOOD	268,570	440,991.9
CONIFER	467,180	767,109.6
GRASSLAND	248,877	408,656.0
WATER	1,103	1,811.1
OTHER	42,852	70,363.0
TOTAL	1,169,768	1,920,759.0

*Note: 1 pixel = 1.642 acres, in this resampled format.

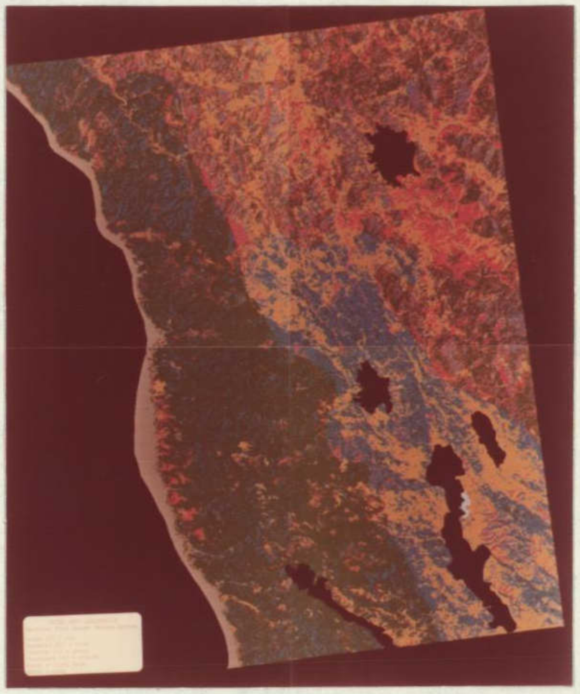


Figure 5. Landsat-derived map for the Ukiah West quadrangle, based on the National Fire Danger Rating System. This four-photo mosaic was produced on the RSRP film annotator using labeled spectral clusters, based on the vegetation classification scheme given in Table 3, from Band 5 of the CDF data set. Model A (grassland) = yellow; Model B (hardwood) = blue; Model F (brush) = red; Model G (softwood) = green; water = light blue; and other = gray.

Table 5. A comparison of the CDF and Fuel Management labels that were assigned to the 113 spectral clusters in the Ukiah West quadrangle.

NORTH COAST INTERIOR ECOZONE

Cluster Number	CDF Label	Fuel Management Class
1	fill	fill
2	fill	fill
3	water	water
4	other	other
5	conifer	chaparral
6	brush	chaparral
7	grassland	grassland
8	conifer	conifer
9	brush	chamise
10	conifer	conifer brush
11	conifer	conifer brush
12	brush	chamise
13	grassland	grassland
14	grassland	grassland
15	conifer woodland	conifer hardwood
16	conifer hardwood	conifer brush
17	barren	barren
18	grassland	grassland
19	conifer hardwood	conifer brush
20	grassland	grassland
21	hardwood woodland	hardwood grassland
22	grassland	grassland
23	hardwood conifer	chaparral conifer
24	other	other
25	grassland	grassland
26	hardwood	hardwood brush
27	other	other
28	hardwood woodland	hardwood brush
29	other	other
30	hardwood woodland	manzanita
31	grassland	grassland
32	brush	manzanita

NORTH CENTRAL INTERIOR ECOZONE

Cluster Number	CDF Label	Fuel Management Class
33	fill	fill
34	water	water
35	brush	chaparral grassland
36	hardwood woodland	grassland hardwood
37	brush	chamise
38	brush	barren
39	hardwood conifer	chaparral
40	hardwood conifer	hardwood conifer
41	hardwood woodland	barren
42	brush	grassland hardwood
43	hardwood conifer	hardwood conifer
44	hardwood woodland	grassland
45	hardwood conifer	hardwood conifer
46	hardwood	hardwood brush
47	hardwood woodland	grassland hardwood
48	conifer woodland	conifer hardwood
49	brush	grassland hardwood
50	hardwood woodland	grassland hardwood
51	hardwood	hardwood
52	hardwood woodland	hardwood grassland
53	hardwood woodland	hardwood grassland
54	grassland	grassland
55	hardwood	hardwood conifer
56	grassland	grassland
57	agriculture	hardwood grassland
58	grassland	grassland
59	grassland	grassland
60	grassland	barren
61	agriculture	hardwood
62	grassland	grassland
63	grassland	grassland
64	grassland	agriculture
65	grassland	agriculture
66	barren	agriculture
67	barren	agriculture
68	barren	agriculture

NORTH CENTRAL COAST ECOZONE

Cluster Number	CDF Label	Fuel Management Class
69	fill	fill
70	water	water
71	conifer	conifer
72	conifer	conifer
73	conifer	conifer
74	conifer	conifer
75	grassland	grassland
76	brush	chaparral
77	grassland	grassland
78	conifer	conifer
79	conifer woodland	conifer grassland
80	conifer	conifer
81	grassland	grassland
82	conifer hardwood	conifer hardwood
83	conifer hardwood	conifer hardwood
84	hardwood woodland	hardwood grassland
85	conifer hardwood	conifer hardwood
86	hardwood conifer	hardwood conifer
87	hardwood conifer	hardwood conifer
88	conifer hardwood	conifer hardwood
89	hardwood conifer	hardwood conifer
90	hardwood	hardwood
91	hardwood	hardwood grassland
92	hardwood	hardwood
93	hardwood woodland	hardwood grassland
94	barren	barren
95	grassland	grassland
96	barren	barren
97	grassland	grassland
98	barren	fill
99 - 113	clouds	fill

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3.2 Labeling Costs for the Ukiah West Quadrangle

Throughout the labeling procedure described in Section 2, the analysts maintained records of the hours required to preprocess the CDF data set and to label the clusters as fuel management classes for the Ukiah West quadrangle. A summary of these hours and their associated costs are listed in Table 6. Obviously, the skill of the analysts and the costs relating to personnel salaries and to computer charges vary between organizations; however, the relative costs associated with the preprocessing phase and the cluster labeling phase should be good indicators of costs that would be incurred on similar interactive display systems. In addition, it is important to note the following four points: (1) The number of man-hours associated with each computer-dependent step does not indicate the period of time required to complete this project. For example, reformatting and loading the data were done on a continuous basis when the computer system was available. On the other hand, selecting spectral blocks and control points and labeling the clusters were done only in blocks of two or three hours per day because of analyst fatigue. In addition, these last two steps were carried out with a team of two analysts because of the amount of ancillary data that had to be handled and analyzed for each spectral block. (2) The costs associated with the selection of spectral blocks and control points must be considered conservative, because the analyst team had orthophoto map sheets on which the CDF coordinates could be located. If these map products had not been available, this step would have required two to three times as many man and computer hours, and the level of accuracy would have been lower. (3) If an additional land use mapping project were to be conducted

Table 6. Cluster labeling costs in dollars for the 1.9 million acres of wildland present in the Ukiah West quadrangle, California.

PHASE	PERSONNEL MAN HOURS	PERSONNEL COST ($15/hour)[1]	RSRP COMPUTER SYSTEM MAN HOURS	RSRP COMPUTER SYSTEM COST ($20/hour)	TOTAL COST
Preprocessing					
1. Reformat and load data	19.00	$ 285.00	19.00	$ 380.00	$ 665.00
2. Select spectral blocks and control points[2]	54.00	810.00	27.00	540.00	1,350.00
3. Organize aerial photos and ancillary data	25.00	375.00	4.00	80.00	445.00
Subtotal	98.00	$1,470.00	50.00	$1,000.00	$2,470.00
Risk (15% of subtotal)[3]	14.70	220.50	7.50	150.00	370.50
Subtotal preprocessing phase	112.70	$1,690.50	57.50	$1,150.00	$2,840.50
Preprocessing cost per acre = $2,840/1,920,759 acres = $0.00148/acre					
Cluster Labeling					
1. Label clusters[2]	42.00	$ 630.00	21.00	$ 420.00	$1,050.00
2. Produce photographic output and tabular data	8.00	120.00	2.00	40.00	160.00
Subtotal	50.00	$ 750.00	23.00	$ 460.00	$1,210.00
Risk (15% of subtotal)[3]	7.50	112.50	3.45	69.00	181.50
Subtotal cluster labeling phase	57.50	$ 862.50	26.45	$ 529.00	$1,391.50
Cluster labeling cost per acre = $1,391.50/1,920,759 acres = $0.000724/acre					
TOTAL	170.20	$2,553.00	83.95	$1,679.00	$4,232.00

TOTAL COST PER ACRE = $4,232.00/1,920,759 acres = $0.00220/acre

1. $15/hour includes salaries and employee benefits.
2. These steps were carried out with a team of two skilled analysts. This team worked only two to three hours per day with the interactive computer system in order to minimize analyst fatigue.
3. Risk includes unforeseen costs such as computer downtime, improperly developed film, and employee sick leave.

2-29

45

with this data set, however, the cost per acre would be considerably less than for the original fuel management project, since two-thirds of the original costs involved preprocessing the data. (4) Finally, the cost per acre ($0.0020) for producing the labeled fuel map for the Ukiah West quadrangle was at least a fourth less than could be expected if conventional Landsat digital data were used. This conclusion is based on a previous Landsat-based fuel mapping project in a 476,000-acre study area in northeastern Mendocino County (see Benson and Katibah, 1978).

4.0 Evaluation of the Etsel Watershed Management Unit

In order to evaluate the accuracy of the labeling procedure that was based on a spectral sample of an ecozone, the 35,000-acre Etsel Watershed Management Unit, located in the North Coast Interior ecozone, was selected as an intensive study site. The Unit is one of 16 such management units located in northeastern Mendocino County for which long term fuel management plans are being developed by personnel of the Mendocino County Fuel Management Committee. The Etsel Unit was selected because it lies entirely within the Ukiah West quadrangle, and because a current vegetation map was available from which current management plans are being implemented. The location of the Etsel Management Unit is shown in Figure 6.

A mask of the Etsel Unit was defined on the RSRP interactive monitor, and the five bands of digital data for the Unit were extracted from the North Coast Interior ecozone. A line printer map, a portion of which is shown in Figure 7, was produced for the Unit using the spectral cluster data (Band 5). Large groupings of the spectral clusters

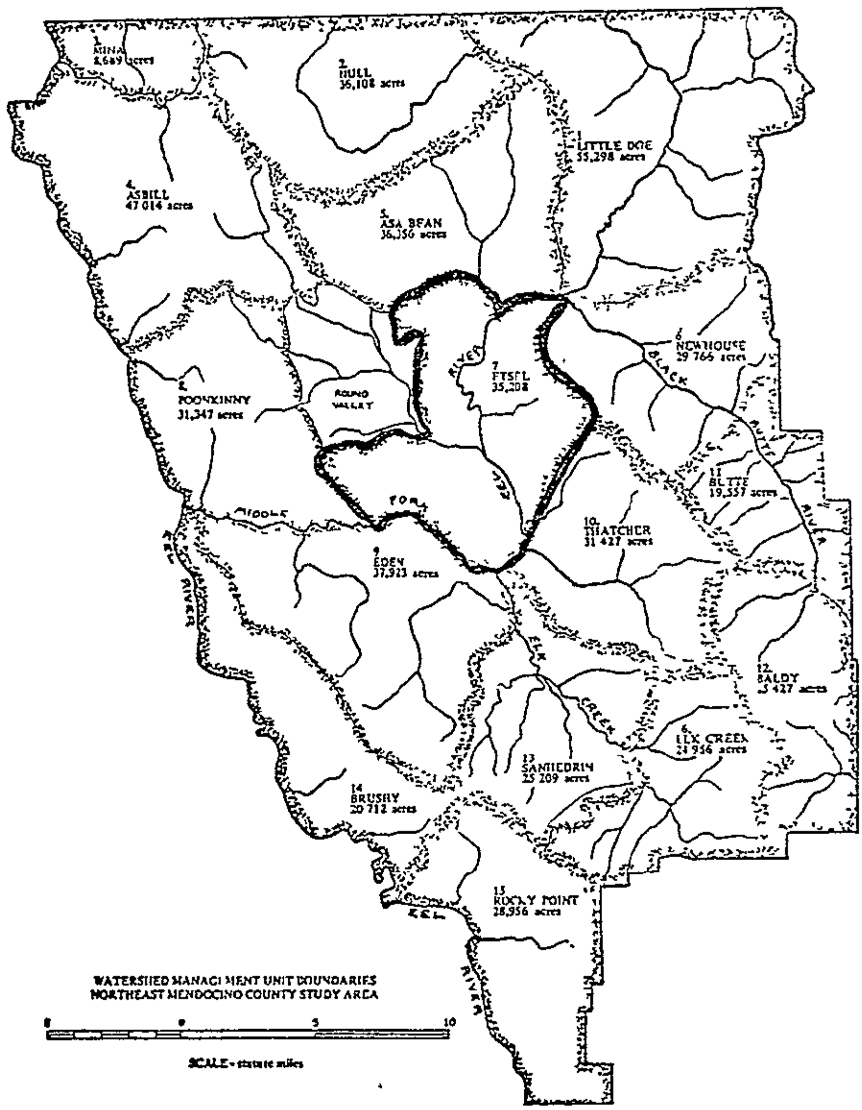


Figure 6. Location of the Etsel Watershed Management Unit in northeastern Mendocino County. This Unit was used as an intensive study site to evaluate the labeling procedure applied to the CDF data set.

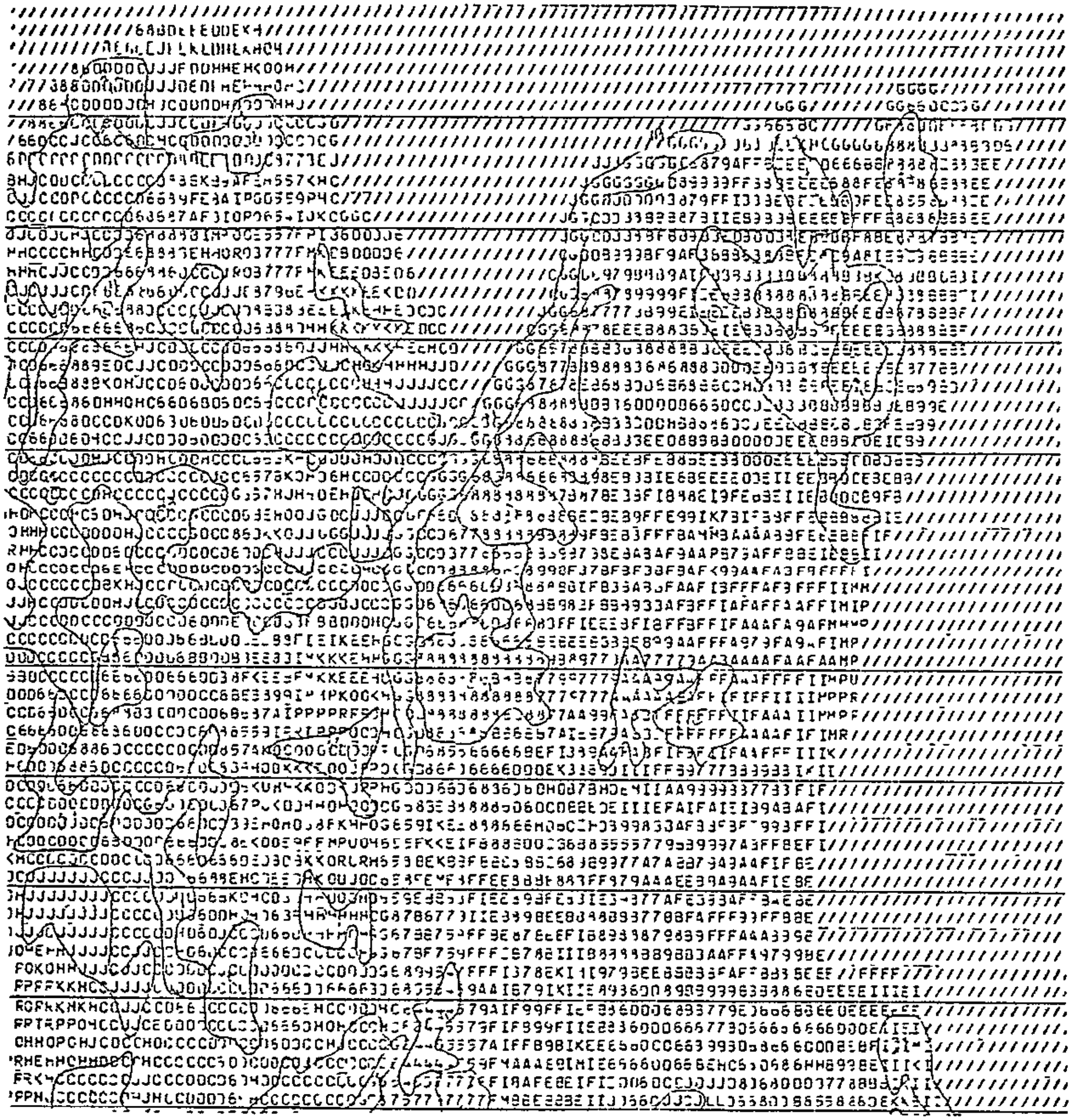


Figure 7. Line printer map of the northeast corner of the Etsel Watershed Management Unit intensive study site. The cluster groups outlined here were located on raw CDF imagery and a ground data map in order to evaluate the labeling procedure and the CDF data set.

present in the Unit were outlined. The centers of the groupings were located on the raw color display, and subsequently were visually transferred to the ground data map that had been overlain on orthophoto map sheets. The fuel management classes assigned to the spectral clusters were then compared with the ground data labels.

The results of the comparisons between the ground data and the labeled cluster data are tabulated in Tables 7a, b, and c. Table 7a compares ground data and individual clusters. This should give an indication of how consistently the reflectance models represent ground conditions. For example, of seven groupings for cluster 12, three represented woodland, two represented woodland/brush, and 2 represented brush. Table 7b compares ground data with CDF labels (see Tables 2 and 5). Table 7c compares ground data with fuel management and National Fire Danger Rating System classes (see Tables 3 and 5).

Although general comparisons can be made, it is difficult to assess the accuracy of either the CDF spectral data set or the fuel management labeling procedure from these tables. The only ground data that were available were quite general both with respect to the minimum mapping area and the ambiguous label "trees" which included both hardwoods and softwoods. Also, the ground data were not registered to the CDF data set, which required manual comparisons; this caused a certain degree of uncertainty in some of the complex vegetation types. In several cases, the analyst who performed the evaluation corrected some apparent errors or omissions in the ground data based on her evaluation of the CDF data set, supporting ancillary data, and personal knowledge of conditions within the test site. Of the three tables, Table 7c gives the best

Table 7a. Comparison of spectral cluster to ground data classes by number of cluster groups (percent of cluster groups) within the Etsel Watershed Management Unit.

CLUSTER NUMBER	GROUND DATA WOODLAND	WOODLAND/ BRUSH	BRUSH	BRUSH/ WOODLAND	TREES	GRASSLAND
1						
2						
3						
4						
5	1(100%)					
6			2(100%)			
7	3(38%)		2(25%)			3(38%)
8	4(36%)				7(64%)	
9	4(21%)	4(21%)	10(53%)		1(5%)	
10	1(33%)				2(67%)	
11		1(33%)			2(67%)	
12	3(42%)	2(29%)	2(29%)			
13	1(8%)					12(92%)
14	6(38%)		1(6%)	2(12%)		7(44%)
15	6(46%)	3(23%)	1(8%)		2(15%)	1(8%)
16	1(33%)	1(33%)			1(33%)	
17						4(100%)
18	2(100%)					
19	2(33%)				4(67%)	
20						8(100%)
21	3(75%)			1(25%)		
22					1(50%)	1(50%)
23					1(100%)	
24						
25	2(100%)					
26	1(100%)					
27						
28	1(33%)				2(67%)	
29						
30					1(100%)	
31	1(100%)					
32	1(100%)					
TOTAL	43	11	18	3	24	36

Table 7b. Comparison of CDF classes to ground data classes by number of cluster groups (percent of cluster group number).

GROUND DATA

CDF CLASSES:	WOODLAND	WOODLAND/ BRUSH	BRUSH	BRUSH/ WOODLAND	TREES	GRASSLAND
BRUSH	8(28%)	6(21%)	14(48%)		1(3%)	
CONIFER	6(33%)	1(6%)			11(61%)	
CONIFER-WOODLAND	6(46%)	3(23%)	1(8%)		2(15%)	1(8%)
CONIFER-HARDWOOD	3(33%)	1(11%)			5(56%)	
HARDWOOD	1(100%)					
HARDWOOD-WOODLAND	4(50%)			1(13%)	3(37%)	
HARDWOOD-CONIFER					1(100%)	
GRASSLAND	15(29%)		3(5%)	2(4%)	1(2%)	31(60%)
BARREN						4(100%)
WATER						
FILL						
OTHER						
TOTAL	43	11	18	4	64	36

Table 7c. Comparison of fuel management classes and National Fire Danger Rating System classes to ground data classes by number of cluster groups (percent of cluster group number) within the Etsel Watershed Management Unit.

	GROUND DATA					
FUEL MANAGEMENT CLASSES:	WOODLAND	WOODLAND/ BRUSH	BRUSH	BRUSH/ WOODLAND	TREES	GRASSLAND
FILL						
WATER						
CHAPARRAL	1(33%)		2(66%)			
CHAMISE	7(27%)	6(23%)	12(46%)		1(4%)	
MANZANITA	1(50%)				1(50%)	
CHAPARRAL-CONIFER					1(100%)	
GRASSLAND	15(29%)		3(5%)	2(4%)	1(2%)	31(60%)
CONIFER	4(36%)				7(64%)	
CONIFER-BRUSH	4(27%)	2(13%)			9(60%)	
CONIFER-HARDWOOD	6(46%)	3(23%)	1(8%)		2(15%)	1(8%)
HARDWOOD-GRASS	3(75%)			1(25%)		
HARDWOOD-BRUSH	2(50%)				2(50%)	
BARREN						4(100%)
OTHER						
TOTAL	43	11	18	3	24	36
NFDRS CLASSES:						
BRUSH	9(28%)	6(19%)	14(44%)		3(9%)	
CONIFER	14(36%)	5(12%)	1(3%)		18(46%)	1(3%)
HARDWOOD	5(63%)			1(12%)	2(25%)	
GRASSLAND	15(29%)		3(5%)	2(4%)	1(2%)	31(60%)
WATER						
OTHER						4(100%)
TOTAL	43	11	18	3	24	36

indication of agreement between the CDF spectral clusters and ground data. With the exception of the manzanita class, the labels of all fuel management classes were similar to the ground data subclasses. That the manzanita class was markedly different from the ground data was probably the result of having no large stands of manzanita within the Unit from which the evaluation could be made. It should be noted that the fuel management class "barren" was identified as "grassland" on the ground data. This was considered an acceptable error since (1) one does not expect to be able to separate dry, annual grasslands from bare soil at this time of year, and (2) such grasslands, for most fire control purposes, are similar to barren areas in that both can be considered as fuel breaks.

The ultimate test of the labels that have been given to the spectral clusters will occur when the fuel managers assess the output products in the field and then derive and implement fuel hazard reduction measures based on those products. Only then will their true accuracy and value in fuel management become apparent.

Areal summaries of the National Fire Danger Rating System and the fuel management classes are tabulated in Tables 8a and b; photographic products illustrating the distribution of the NFDRS vegetation models and the three brush classes of the FMC, viz., chamise, chaparral, and manzanita, are illustrated in Figures 8a and b, respectively. These photographic products have been given to fuel specialists, who are implementing fuel modification programs within the watershed and currently evaluating them.

Table 8. Tabular summaries of the pixel count and associated acreages in the Etsel Watershed Management Unit for (a) National Fire Danger Rating System vegetation models and (b) the fuel management classes.

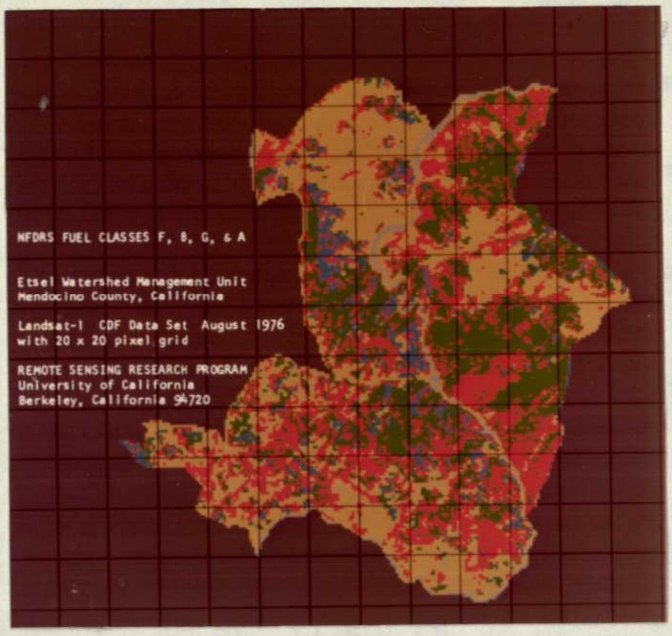
(a)
NATIONAL FIRE DANGER RATING SYSTEM

VEGETATION MODEL	PIXELS	ACRES*
F: BRUSH	6,986	11,547.9
B: HARDWOOD	1,328	2,195.2
G: CONIFER	6,178	10,212.2
A: GRASSLAND	7,432	12,285.1
WATER	-0-	-0-
OTHER	468	773.6
TOTAL	22,392	37,014.0

(b)
FUEL MANAGEMENT CLASSES

VEGETATIVE TYPE	PIXELS	ACRES*
CHAMISE	5,494	9,081.6
CHAPARRAL	1,424	2,353.9
MANZANITA	68	112.4
HARDWOOD	1,328	2,195.2
CONIFER	6,178	10,212.2
GRASSLAND	7,432	12,285.1
WATER	-0-	-0-
OTHER	468	773.6
TOTAL	22,392	37,014.0

*Note: 1 pixel = 1.653 acres.



NFDRS VEGETATION MODELS

(a)

brush (F) - red
hardwood (B) - blue
conifer (G) - green
grassland (A) - yellow
other - gray

FUEL MANAGEMENT CLASSES
Brush

(b)

chamise - red
manzanita - orange
chaparral - yellow
other - gray

Figure 8. The distribution in the Etsel Watershed Management Unit of (a) National Fire Danger Rating System vegetation models, and (b) three brush classes (chamise, chaparral, and manzanita) of the fuel management classes. These two photo maps were produced on the RSRP film annotator by relabeling the spectral clusters of the digital CDF data set. The grid represents 20 points-by-20 lines.

5.0 Work To Be Conducted in 1980-81

Based on the results of the past year's fuel mapping efforts, some highly significant follow-up work will be done by the resource managers at no cost to this NASA-funded project. Specifically, fuel managers in the US Forest Service and the CDF in northeastern Mendocino County will devote 4-man months of effort to collecting ground data in order to quantify the fuel management labels that have been given to the CDF data set clusters. Since the quantification of wildland fuels in terms of tons/acre is an important data requirement for managing these fuels, important management decisions will soon be made and implemented. Two types of decisions will be involved. On the one hand, these data dictate whether a fuel type should be modified and, if so, how it should be modified. On the other hand, in a series of studies being conducted throughout California, investigators are seeking to determine the possibility of using wildland "waste" products, such as brush, hardwoods, and logging slash, as an alternative to energy derived from fossil fuels.

Regardless of the fuel management objective -- reducing fire hazards or harvesting energy resources -- the data from which the information requirements are derived must be collected in a timely and cost effective manner. The data must be current in order to meet changing policy decisions, and the data must be collected inexpensively because the intrinsic value of the fuel is either negative, as in the case of fire hazards, or low, as in the case of an energy resource. Our work to date on this project prompts us to predict that Landsat will prove to be the ideal data source in relation to these requirements.

The procedure that will be used in northeastern Mendocino County to quantify wildland fuels will be as follows:

1. Define ground sampling frame. The sample frame will be limited to the NFDR class F (chamise, manzanita, and chaparral).
2. Procure large scale sample photography. The U.S. Forest Service will obtain large scale (1:1000) 35mm photography of a number of transects which represent Class F. These photos will be used to define ground sample plots, to quantify ground cover, and to assist in field operations.
3. Collect ground data. Field crews from the U.S. Forest Service will collect ground data from a sample of the large-scale photo plots. These ground data will be used to estimate fuel loads in tons/acre.
4. Correlate ground, photo and CDF spectral classified data. Statistical relationships will be developed between the three sample stages.
5. Expand fuel loading estimates to management units. If valid statistical relationships can be developed in (4) above, the fuel loading estimates will be expanded to applicable fuel management units such as the Watershed Management Units and the Covelo Ranger District.
6. Implement final modification plans. Based in part on the information from the fuel loading maps produced in (5), fuel modification programs will be implemented by personnel of the U.S. Forest Service and the California Department of Forestry in northeastern Mendocino County.

6.0 Literature Cited

1. Benson, Andrew S. and Louisa H. Beck, 1979. An investigation of the uses of digitally mosaicked Landsat data for mapping wildland fuel hazards in Mendocino County, California. Final report for NASA Ames-University of California Consortium No. NCA2-OR050-903. Space Sciences Laboratory Series 21, Issue 1. University of California, Berkeley, California, 94720.

2. Benson, Andrew S., Louisa H. Beck, and Charles E. Henderson, 1979. Fuel mapping in relation to the management of brushlands and timberlands in California. Chapter 2 in Applications of Remote Sensing to Selected Problems within the State of California. Space Sciences Laboratory Series 20, Issue 25. University of California, Berkeley, California, 94720.

3. Benson, Andrew S. and Edwin F. Katibah, 1978. Fuel mapping in relation to management of brushlands and timberlands in Mendocino County, California. Chapter 2 in Applications of Remote Sensing to Selected Problems within the State of California. Space Sciences Laboratory Series 19, Issue 64. University of California, Berkeley, California, 94720.

4. Deeming, J.E., R.E. Burgan, and J.D. Cohan, 1978. The national fire danger rating system. USDA Forest Service General Technical Bulletin INT-39. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

PART II

FORSYTHE PLANNING EXPERIMENT

APPLICATION OF LANDSAT AND GEOGRAPHIC INFORMATION SYSTEMS TO PLANNING PROCESSES IN MENDOCINO COUNTY, CALIFORNIA

by

Charles E. Henderson

PART II

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1.0 Project Description

The Forsythe Planning Experiment (FPE) is a demonstration project designed to explore the uses of Landsat satellite data as a general planning tool in Mendocino County, California (see Figure 1). This work is sponsored, in part, by NASA Grant NSG 7220 to the Remote Sensing Research Program (RSRP) of the University of California, Berkeley. The purpose of the project is three-fold:

1. To acquaint Mendocino County planners, resource managers and the general public with the advantages, limitations, and potential uses of Landsat satellite data and Landsat derived map products.
2. To demonstrate the feasibility of combining Landsat satellite digital data with other resource data within a computer based Geographic Information System and through this demonstration provide a time- and money-saving planning tool.
3. To develop specific output products for use in Mendocino County's General Plan update, re-zoning and land use permit processes.

To accomplish these purposes two geographic information systems are being utilized: (1) the interactive graphic display facility at the Remote Sensing Research Program, Space Sciences Laboratory, U.C. Berkeley, and (2) the Landpak Resource Information and Mapping System provided by the Berkeley office of Earth Satellite Corporation. Each system, with its respective capabilities and data requirements, is being studied to determine the optimum information handling hardware configurations and software support needed in helping to satisfy various resource information needs in Mendocino County.

Three study areas have been selected for testing these systems (see Figure 2). The study areas are located between the major population centers of Ukiah and Willits along Highway 101. The most predominant land feature is Forsythe Creek which comprises the northernmost headwaters of the Russian River. Thus, the project has been named the Forsythe Planning Experiment. For each of the three study areas a different data base and a different computer configuration is being applied to the resource features within the study area. During the course of the experiment the advantages and limitations of each system will be demonstrated as they apply to county needs. The rational for the creation of three study areas, each overlapping and in the general vicinity of the Forsythe drainage (see Figure 2), can be understood by reviewing each study area in detail.

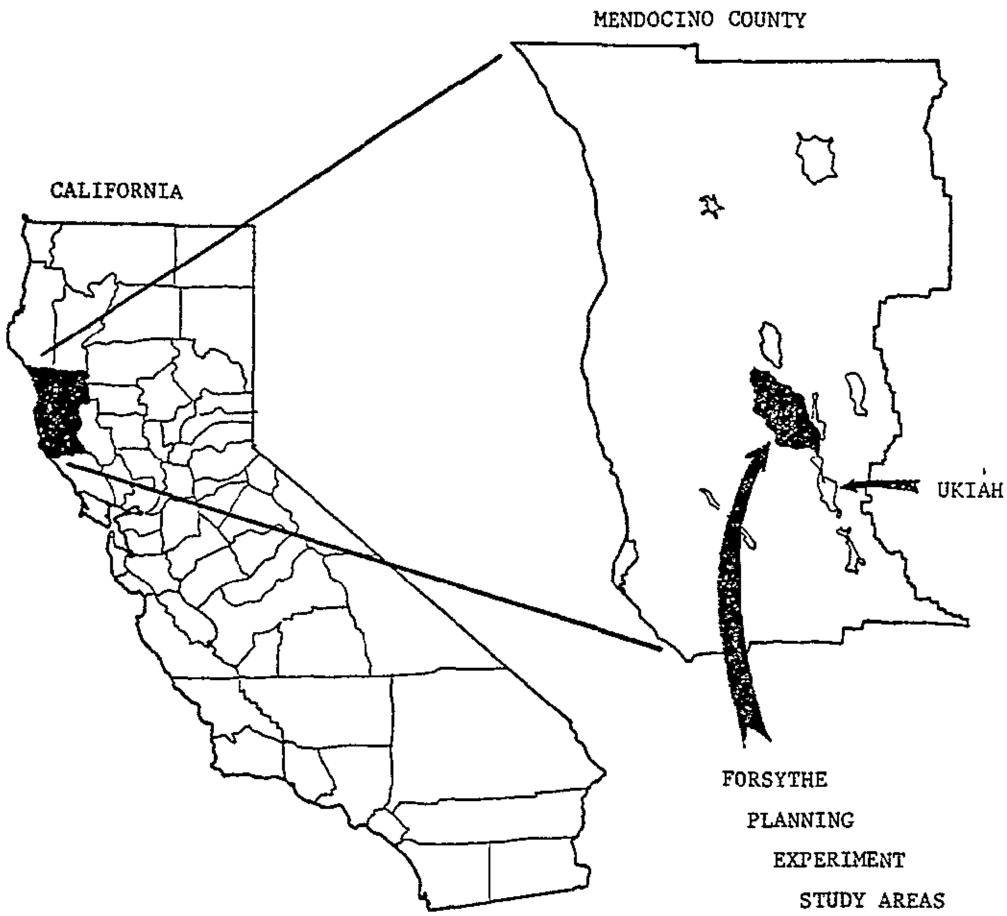

Figure 1. The Forsythe Planning Experiment Study areas are located between the cities of Ukiah and Willits in Mendocino County. Rapid population growth and resultant land development (both legal and illegal) are taking place in the study area. Pressures on timber production capability, rangeland productivity, fire suppression capabilities and the self support of the County are increasing as development continues. The Forsythe Planning Experiment is a demonstration of remote sensing and geographic information system applications to the difficult problems of general and site specific planning.

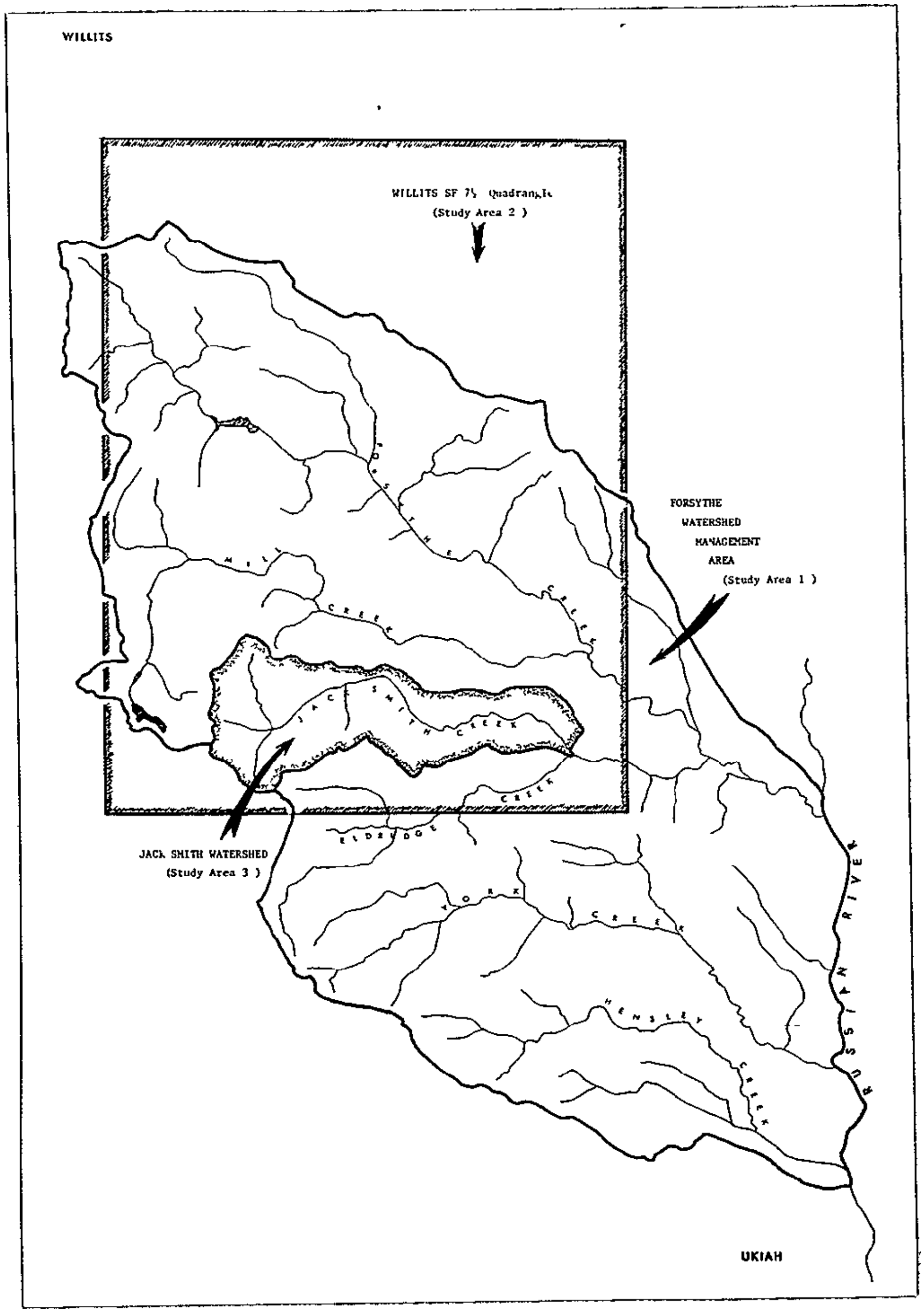

Figure 2. Three study areas, each to be portrayed by different types of information, and overlays of data, are addressed by the experiment. Study area 1, the 45,000 acre Forsythe Watershed Management Unit, is comprised of seven sub-watersheds and their intershed facets. Study area 2 is the area covered by the Willits SE $7\frac{1}{2}$' quadrangle map. This area was selected for Digital Elevation Model (DEM) coverage. Study area 3 is the Jack Smith Watershed. Resource data from this watershed, the most complete of the three study areas, will be incorporated into the Landpak Resource Information and Mapping System. All three study areas will utilize a normalized Landsat vegetation classification for baseline vegetation data.

Study Area 1 - Forsythe Watershed Management Unit (45,265 acres)

In keeping with the intensive resource inventory and coordinated resource format used by the California Department of Forestry elsewhere in Mendocino County (Benson, Beck & Henderson, 1979), this area is comprised of several sub-watersheds, all of which drain into a common water system, the Russian River. The sub-watersheds form a distinct management unit that conforms to watershed boundaries and is compatible with standard map scales, sizes and accounting procedures. It is the long range goal of the Mendocino County Planning Department to compile all resource information on a watershed boundary basis (Mendocino County Draft General Plan, 1979) in order to facilitate the future inventory effort. The Mendocino County planning staff also indicated the desirability of developing and maintaining an interface of vegetation data for this area with data relative to an ongoing gravel extraction analysis for the Forsythe Creek drainage. Consistent with this objective, a Landsat Vegetation/Ground Cover Map is being prepared for Study Area 1.

Study Area 2 - Willits SE 7½' Quadrangle (37,081 acres)

Study Area 2 was chosen to interface with the current manual information system now being used in Mendocino County. The manual system compiles resource information for each of seventy-two 7½' quadrangles that cover the county. Of the five quadrangles which cover Study Area 1, the Willits, SE quadrangle covers the largest portion. For this reason it was selected for Study Area 2.

For Study Area 2 an interactive computer file is being built. Collectively the different layers (overlays) in the file will contain many important types of resource-related information including a Landsat vegetation/groundcover map, soils data, solar illumination data, and data on elevation, slope and aspect.

Study Area 3 - Jack Smith Watershed (3,283 acres)

Of the three study areas the most intensive demonstration will take place in Study Area 3. For this small watershed a detailed interactive data file will be constructed. This data set will include the Landsat, soils and topographic data mentioned for Study Area 2, road networking, individual residences, property ownership boundaries with all associated annotations - (e.g. assessed value, legal description, zoning, preservation zone(s) if any, legal ownership, etc.) - and other features recorded by the county assessor and the county planning department.

This data set will utilize the previously mentioned Landpak Resource Information and Mapping System.

Data compiled for Study Areas 2 and 3 will be used to demonstrate the interactive modeling capability of computer and computer-driven video display systems. These systems will be used to compile useful types of information that have been either too time consuming or too costly for previous planning and resource management efforts to consider.

These include a percent stocking map for timber producing soils, a potential resource production map for timber and rangeland areas, a current resource production map, and a map which expresses current timber production as a percent of potential production. These and other components derived from the interactive file are described in section 4.3.0-5 and are scheduled for completion in FY 1980-81. These data types are the real fruits of the computer systems that are being compiled. It is our goal to make these systems applicable to current planning needs so as to successfully demonstrate the utility and advantage of satellite and computer information systems.

A primary focus of the preceding year's effort under this project has been the testing and evaluation of DMA Digital Terrain Tape (DTT) products. It was our hope that these elevation models would be directly applicable to the creation of slope, aspect and other data vital to the Forsythe Planning Experiment. Our conclusion has been to discard this data type because of (1) difficulties in registering it to other data inputs and (2) at least in some instances, the unreliable accuracy and precision inherent in the data itself (see section 3.1). We have turned instead to a new product, Digital Elevation Models (DEM) described in section 3.2. The DEM elevation models have proved highly reliable and are now integrated into our data files.

In the previous year we have also developed, and are now in the process of testing, the utilization of solar illumination models and the normalization of Landsat data using these models. These techniques are described in section 3.3. It is our anticipation that normalized Landsat products will have significant applicability in improving the accuracy of Landsat classification in all wildland areas.

The remainder of this report describes our approach to the technology transfer situation we have encountered in Mendocino County, the background of the planning effort there, detailed descriptions of the past year's technological work, and descriptions of the tasks that we currently anticipate conducting in the coming year.

2.0 Background

2.1 Historical Perspective

Mendocino County, like other rural communities throughout Northern California, is experiencing a major influx of people seeking a place in which to live and a means of support. The population growth within Mendocino County for the past 80 years and projections to the 1985 (Mendocino County Planning Department) can be seen in Figure 3. Forecasts for the year 2000 call for a county-wide population of approximately 100,000.

The heavy influx of people has put, and continues to put, unusually heavy pressures on agricultural, range and timber producing lands. In many instances, developers and owner-builders have built homes, shopping centers, schools and roads over lands that had previously provided soils for grapes and orchards. In recent years the expansion of individually owned parcels and homes has extended into the upland forests and oak woodland. Many large ranches in the upland areas, which had traditionally

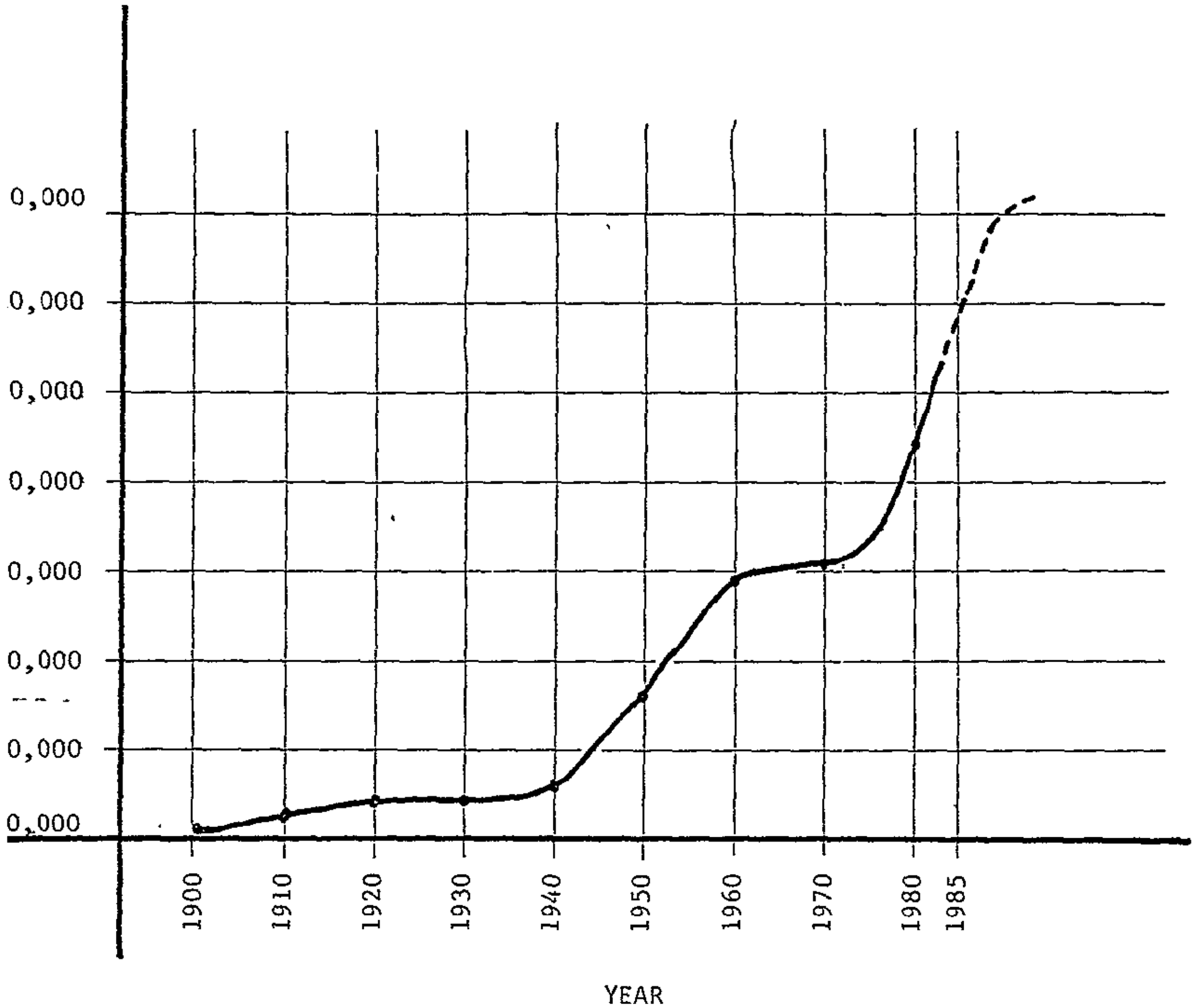

Figure 3. Population in Mendocino County. Source: U.S. Census and the Mendocino County Planning Department, including extrapolations to the year 2,000.

raised sheep, cattle and timber, and thereby provided the major exports from Mendocino County, have been subdivided into parcels ranging from under an acre to 200+ acres.

Currently in Mendocino County there are between 14,000 and 17,000 legal and buildable parcels. Only a fraction of these have been developed (Hancock, et. al. 1977). For the most part, these parcels no longer provide the economic activity that was provided by the larger ranches. Smaller parcels are difficult to manage as ranches, year-by-year allocations for cattle grazing cannot be rotated, and much good land is lost to roads and developments. Additionally, rural development has brought domesticated household animals into the hills. Uninhibited in the rural environment, family dogs run in packs and cumulatively have destroyed significant numbers of sheep, diminishing the productivity and profit margin of the sheep industry.

To aggravate the problem, many people who have chosen to live on upland parcels away from the municipal services are building homes without applying for building permits and, in many cases, they are building structures that do not comply with the adopted Uniform Building Code. Because they are not recognized by the building department, these structures often are not appraised by the county assessor. But all upland homes depend on county services, and so a significant portion of the tax burden has been placed on urban taxpayers (ibid).

These problems escalated to the boiling point in 1978. Prompted by concerned citizens, the California State Attorney General brought suit against Mendocino County and forced a redesign of the General Plan to comply with State general plan guidlines. A moratorium on the erection of new subdivisions, both major and minor, has been ordered until an acceptable general plan is adopted. This moratorium is still in effect as of this writing.*

The overall impact which results from lands being removed from resource production can only be estimated, but more importantly, the ability of the county government to supply services and receive revenue from these lands has been the subject of growing citizen and public agency concern. If the resource production capability of an area is removed and the need for government services (fire protection, road maintenance, medical, welfare, judicial service, etc.) is increased, how will the economic base of the county be increased accordingly without state and federal subsidy and decreasing self-sufficiency?

Faced with an antiquated and inaccurate resource data base and an "illegal" existing general plan, the County Planning Department has taken on the task of designing a new comprehensive general plan that will meet the state requirements and provide Mendocino County with some solutions to the complex situations described above.

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*It should be noted that the moratorium on parcel subdivision has just entered its second year. Members of the Planning Department staff, under severe pressure from developers, the County Board of Supervisors and other special interest groups, selected a data base and have written what will hopefully be an acceptable general plan. Plans to incorporate an updated resource information base, which could include Landsat-derived vegetation data and other products, has been slated for the "second phase" of the General Plan Update which will follow the release of the subdivision moratorium. The results of the Forsythe Planning Experiment will determine, for all participants in the General Plan Update, the usefulness and appropriate utilization of Landsat-derived products, and will enable such products to be directly utilized in the making of land use decisions within the study area.

2.2 Current Planning Efforts in Mendocino County

To meet the mandate of the State Attorney General, the Mendocino County Board of Supervisors, the Planning Commission, and the Planning Department are developing and implementing an array of processes and programs, including the following:

1. Formation of Citizen Advisory Committees

   Seventeen Citizen Advisory Committees (CACs) have been created to develop goals and objectives for the county-wide General Plan as well as for each CAC area. These groups have members appointed by the Board of Supervisors and meet monthly. Each group has subcommittees which make recommendations to the CACs on specific General Plan elements including land use, conservation, transportation, seismic safety and scenic elements.

2. Development of a Resource Information Library

   Funded by the California State Office of Planning and Research, the Planning Department has established a resource inventory library. It contains a growing collection of environmental impact reports, maps and resource inventories from a broad cross section of State, Federal and County resource agencies and consulting firms. The library is well designed and in the future could provide invaluable assistance to planners, consultants and developers.

3. Participation in the Forsythe Planning Experiment (FPE)

   Members of the Mendocino County Planning Department staff have recognized the potential applicability of Landsat data and Landsat-derived resource map products, as well as the potential of computer géographic information systems (GIS) to general planning. Hence, they have joined with personnel of our Remote Sensing Research Program to explore and apply sophisticated remote sensing and computer mapping techniques to the planning effort with the long range goal of acquiring a general purpose computer information system with Landsat capability for in-county operational use.

The Potential System User

Although the primary collaborators in the Forsythe Experiment are the Mendocino County Planning Department and Planning Commission, the successful implementation of an operational resource information system in Mendocino County still requires involvement by many participating agencies. The resource information library which has now been in existence for one year, has already been used extensively, especially by personnel from state and federal agencies operating within the county.

A listing of the potential users of a geographic information system of the type which we are now helping to develop, utilizing Landsat as an integral part of the resource data structure, includes the following agencies within Mendocino County:

County Planning Department
County Assessor
County Building Department
County Health Department
County Election Department
County Department of Public Works
California Department of Forestry
California Department of Transportation
California Coastal Commission
Bureau of Land Management
United States Forest Service
U.S. Army Corps of Engineers

This list does not include representatives from the private sector (citizen's groups, private contractors and individuals) who likewise are potential users.

2.3 Strategy for Technology Transfer

Although the output products may be useful and the technology an improvement over existing methodologies, the process of technology transfer does not happen automatically.

County administrators live in a political milieu and make decisions based, in large part, on political considerations. The acceptance of any new technology has the potential of upsetting the political equilibrium and therefore the decision-making process within the political structure. We expect the acceptance and support of any new technology from administrators and elected officials to go slowly, if at all, and we also expect that the technology will be approached with a watchful eye to the social and political consequences.

The adoption of new technologies, which would incorporate computer based resource management through the use of Landsat data, would necessitate a complete revision of existing methods. There is substantial monetary and manpower investment that the County must balance against the expected benefits. These costs include:

1. retraining of individuals
2. hardware and software acquisition
3. data acquisition
4. digitizing of many data types
5. employment and training of new support personnel
6. system upkeep
7. additional overhead

These costs are all substantial and it is part of this demonstration project to quantify the costs of technology implementation as well as to demonstrate the benefits.

Presenting the County with alternatives to existent operational planning methodologies can also present a threat. Any recommendation advocating the use of Landsat data, interactive computer graphics, and complex information systems could be interpreted as meaning that planning will suddenly be in the hands of computer programmers, and that the making of decisions will be relegated to the technological "few" who can understand the machines. Talk of standard deviations, multispectral scanners, multiple regression techniques, and clustering algorithms can come out sounding like "Star Wars" to the non-technically minded. Yet these are the very people who must ultimately make decisions as to the implementation of the new technologies.

"De-Mystification"

The strategy being used in Mendocino County can be summed up as a "de-mystification process". User initiation into the powers of computer wizardry is being accompanied by realistic admissions of limitations, system failures and problems yet to be solved.

The technology is not being sold as a panacea for the dilemmas of general planning but rather as a possible innovative solution that should be looked upon with hope as well as skepticism.

From the outset, various categories of "planners" from Mendocino County have been involved in the conception of the Forsythe Project. Many of them have visited our Remote Sensing Research Program and have seen our interactive display system. Future meetings will involve planners in vegetation classification assignments, and the generation of criteria for output products.

County administrators and supervisors will be contacted individually after the data files have been built in order to present the technological capabilities in a clear and concise fashion. Public presentations and media coverage will aid in developing community awareness and excitement, but will be tempered with realism and the acknowledgement that there are operational practicalities.

3.0 Technological Accomplishments

3.1 Evaluation of Digital Terrain Tapes

The Defense Mapping Agency Topographic Center (DMATC) has produced digital terrain tapes (DTTs) for the entire United States. DTTs have been modeled at a 1° quad format using elevation data prepared by the USGS at a base scale of 1:250,000. For the 200-foot contour intervals found on these maps, elevations have been digitized and interpolated to yield a grid cell file with pixel resolution equal to 60 m^2 (208 ft.^{2}).

A major component of the Forsythe Planning Experiment has been the utilization of elevation data (e.g. DTTs) to derive slope, aspect and solar illumination models. The accuracy of these models is completely dependent upon the accuracy of the elevation data. (See Appendix 1 - Slope, Aspect & Solar Illumination Derivation). In attempting to utilize the DTT data set for slope, aspect and solar illumination models, we have had the opportunity to thoroughly evaluate DTT usefulness and we can report the following major findings:

1. The horizontal accuracy (i.e. overall correct positioning of the data set) is well below the levels required by site-specific planning tasks. DTT data simply do not represent elevation values which correspond to ground data. Conversations with USGS photogrammetry personnel verify the gross errors which are associated with the DTT data. True, in some areas the accuracy

of the DTT allows a fairly good fit with other data sets, but in the Forsythe Area no consistent control points could be located and reasonable reformatting of the data was impossible. This lack of accuracy can be attributed to inadequacies in the base map from which the data was derived. In the words of the user guide provided by the National Cartographic Information Center (NCIC):

> "The accuracy of the digital terrain tapes is no better than the accuracy of the stable base 1:250,000 scale map sheets from which they were digitized. Neither the maps nor the tapes have been completely tested for vertical accuracy. However, the computer interpolation between contours on the map to produce a matrix of equally spaced elevation values is more consistent than manual interpolation. The Geological Survey does not assume any responsibility for the accuracy of the tapes..."

2. Inaccuracies in the DTT interpolated elevation values and the nature of the interpolation algorithm used in the creation of DTTs are such as to yield a data file which in many cases misrepresents the actual topography. The illustrations in Figure 4 depict an imaginary elevation transect along with a transect of the DTT elevation model which would supposedly represent the topography. The interpolated elevation algorithm used in DTT creation truncates mountain tops and ridge lines by assigning to individual pixels elevation values which are the average of the elevations of the two nearest contour lines. The mountain peak 'B' almost reaches 600' but because it stays below the 600' mark it is reduced to a 400' plateau. Similarly, valley 'C' is filled and peak 'D' again truncated. Such handywork may be

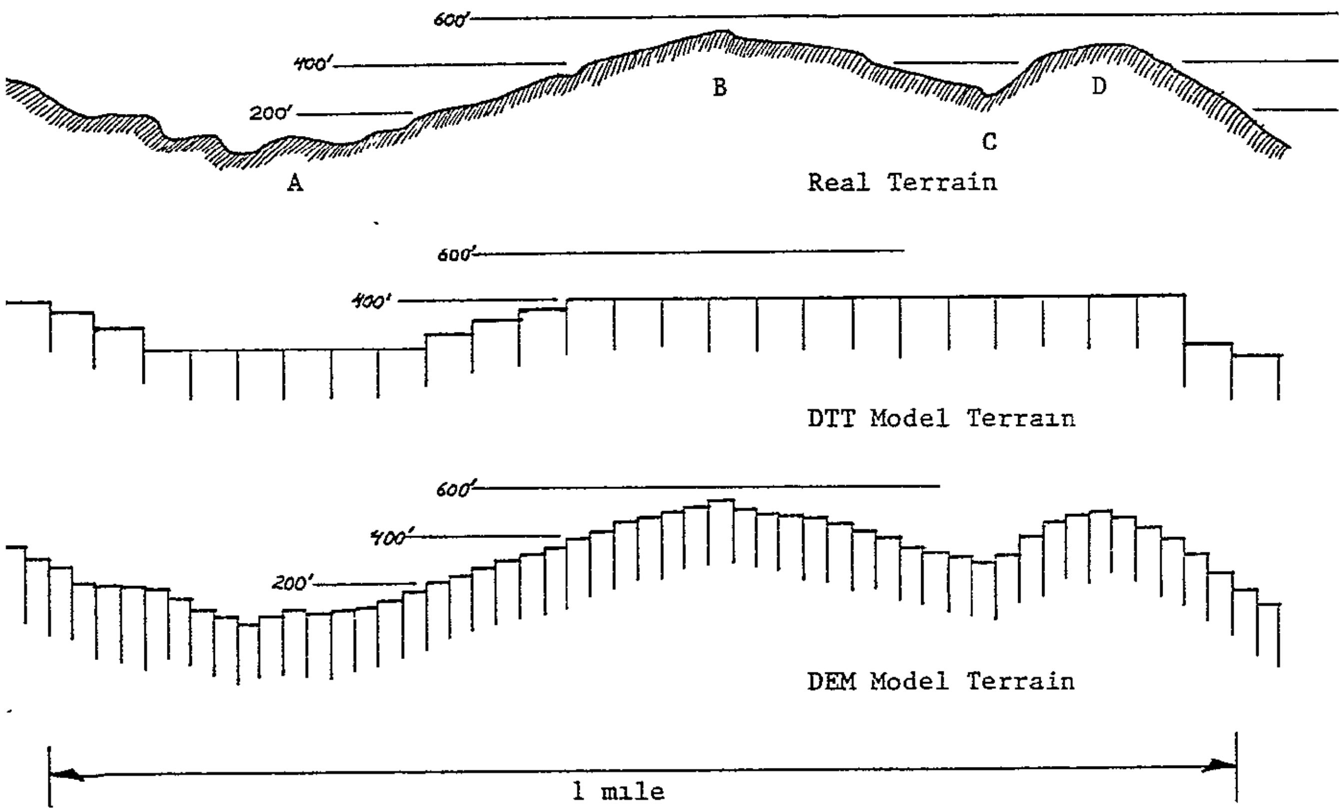

Figure 4. DTT vs. DEM terrain models shown over an imaginary transect. Note that the DTT's interpolation algorithm in some cases truncates mountain tops and fills valleys. By contrast, DEM terrain models represent the real terrain with excellent accuracy. For the Willits SE quadrangle, sample elevations yielded a 4.4m Root Mean Square Residual.

in the interests of would-be cut and fill developers, but clearly this sort of interpolation only causes confusion for the critical, potential user.

Creating slope and aspect values only intensifies the problem. For example, terrain near mountain tops is incorrectly modeled to indicate zero slope. From a planning point of view this would indicate, erroneously in most instances, that mountain peak areas are ideal for development and capable of supporting septic systems, roads and other ammenities that, if permitted at all, would require prohibitively expensive amounts of cut and fill.

After many attempts to rectify the reformatting difficulties mentioned previously, and after analyzing the slope and aspect data created from DTTs, it was our decision to discard the DTT data and omit it from the demonstration experiment.

To replace the DTT elevation data we chose to incorporate a relatively new digital elevation product called the Digital Elevation Model (DEM).

3.2 Enter the Digital Elevation Model (DEM)

The DEM is a precision photogrammetric product created by replotting the original quad centered photography used to make orthophotoquads. From the aerial photography control points are determined and elevation profiles (from east to west) plotted using automated machine photomappers or, as in the case of the FPE, manual plotting devices. Elevations between profiles are then interpolated and a digital file is built with a simple pixel representing $30m^2$ on the real topography. By the specifying of additional profiles and by the increasing of elevation readings along each profile, accuracy can be greatly increased.

The Digital Cartographic Applications Program of the USGS is currently compiling DEM tapes on a quad-by-quad basis for the entire United States. These products are compatible with standard USGS maps and Digital Line Graphs (a 7½' quad format product which provides map data other than elevation on computer compatible tapes). Since over 40,000 7½' quads are required to cover the United States, the USGS is selecting areas of highest demand and intensive research for initial DEM compilation.

Arrangements were made with the Plans and Productions Department of the Western Regional Mapping Center of the USGS to create one DEM tape for the demonstration. Since 5 quads are required to cover 100% of the FPE study area, we chose the Willits SE quad which contained the greatest portion of the study area within its boundaries. Much of the cost for preparation of the DEM was borne by the USGS.

Additional arrangements were made to include areas immediately adjacent to the quad boundary (extending 1 mile to the west, south and east) so that convolution experiments to determine annual solar illumination and other values could be conducted.

The accuracy of the DEM product is graphically shown in Figure 4. Compared with DTT products described earlier the DEM data is emminently superior. The reduced pixel area ($30m^2$) coupled with the fact that DEM's are created directly from original photography makes the models as accurate as, (or in many cases more accurate than), published 7½'map material.

Empirical testing of the DEM product using visual measurement from the color display at RSRP bears out the remarkable accuracy of this new data set. It should be noted that within the study area several outcroppings of Franciscan rock plunge out of the rolling slopes and in some cases reach heights of 100' or more. These formations were actually visible on the DEM terrain data, and subsequent models (viz. the solar illumination models described in the following section) made these formations visible on the color display monitor.

To evaluate the accuracy of interpolated elevation values, 29 random sample points (pixels) were chosen.* Elevations were measured directly from original photography from each sample coordinate and compared with the interpolated value. As seen in Table 1, maximum elevation errors were +8.9m and -7.6m with an average residual (RMSE) of 4.4m. Photogrammetrists from USGS attribute this high degree of accuracy to the quality of precision control for the Willits SE quad. The accuracy specified by the request was 14m RMSE.

3.3 Normalization of Landsat Data to Correct for the Effects of Variable Solar Illumination

Before Landsat 1 was launched in July 1972, much discussion among potential Landsat users was voiced regarding the appropriate time of day for the satellite to pass over the continental United States. On the one hand, geologists and other earth scientists argued for an early morning data acquisition time (between 9:00 and 10:00 AM) so that the sun angle at the time of acquisition would provide imagery having sufficiently long shadows to maximize the perceptability of terrain relief. They wanted to use Landsat to reveal landforms, fault lines and potential

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*evaluation was conducted by the USGS upon completion of the elevation model.

TESTPOINT INTERPOLATION ACCURACY

PT	X	Y	Z	VZ
11660	473447.6	4343860.2	412.4	5.2
11661	468276.9	4344121.8	292.6	-5.7
11851	479040.5	4345003.7	225.6	-1.1
11650	473599.6	4351077.7	372.8	0.8
11651	468492.6	4350564.8	655.9	-6.5
11861	479315.5	4351359.6	505.7	-2.4
10	473446.4	4343862.9	412.4	5.4
11	468275.4	4344119.9	292.6	-6.0
12	479042.0	4345003.7	225.6	-1.3
13	473600.5	4351078.9	374.0	-0.3
14	468492.0	4350564.5	655.9	-6.5
15	479316.1	4351359.3	499.6	3.8
1652	471477.1	4347617.1	822.7	-7.6
1653	473295.8	4347359.8	425.2	7.3
1654	473971.8	4347906.9	312.1	3.6
1655	475067.1	4349004.6	508.1	-1.2
1656	472113.0	4350147.5	517.2	8.9
11640	473171.7	4358157.2	469.7	0.9
11641	468264.1	4358271.8	605.0	2.5
13	473600.5	4351078.9	371.6	2.2
14	468492.0	4350564.5	655.9	-6.5
15	479316.1	4351359.3	504.1	-0.8
16	473171.4	4358156.3	469.7	1.0
17	468264.7	4358271.5	605.0	2.6
1658	476861.9	4354991.4	832.1	1.9
1660	473534.3	4351776.3	381.0	-1.8
1661	472283.6	4351703.8	375.8	3.8
1662	470762.3	4352241.0	398.1	6.1
1663	472688.1	4357183.5	473.4	-0.2
RMSE	29 POINTS			4.4

Table 1. Sample-Determined Accuracy of DEM data set.

mineral deposits. Forestry, agriculture and rangeland scientists were opposed to an early hour of acquisition, arguing that variable shadow lengths (caused by variable slopes) and variable solar illumination, accentuated by a low sun elevation, would confuse their efforts to determine vegetation type and condition.

As it was, a compromise was reached in which NASA programmed the satellite to pass over the continental United States between 9:15 AM and 10:15 AM local time.

From a forester's standpoint the geologists were given the better half of the bargain. Even at the most favorable latitudes, and even during the longest days of the year when the sun reaches maximum elevation, sun elevations (above the horizon) at the time of Landsat data acquisition never exceed 60°. As a result of variable terrain alone, incident solar illumination (measured in lumens m^{-2}) has been estimated to vary by a factor of two between 30 percent northwest-facing slopes and 30 percent southeast-facing slopes.

This drastic variation in solar illumination has caused considerable confusion to both manual and digital analysis of Landsat data. Variable solar illumination can cause similar vegetation types to be dis-aggregated or divergent vegetation types to be confused. As a result, classification methodologies have involved detailed classification (up to 100+ classes) that must be re-numbered (grouped) together manually to produce accurate and meaningful output products.

A major component of the FPE is the testing of several procedures which have a high theoretical promise to correct for variable solar illumination.

These procedures utilize the accurate Digital Elevation Models discussed previously. From the DEM data a unique Solar Illumination (SI) band has been created which simulates the direct sunlight illuminating each Landsat pixel at the time of the Landsat satellite pass. Figure 5 shows the resulting SI band for the entire Willits SE $7\frac{1}{2}$' quadrangle (Study Area 2) at the time when this area was scanned by the Landsat MSS system (June 27, 1976).

The SI band has been used to normalize the Landsat data to subtract for the effects of variable sunlight. If proven successful the techniques developed by the proposed test procedures could have substantial impact on the accuracy of Landsat classifications in wildland areas. Further, utilizing solar illumination data should have significance to the utilization of Landsat 'D' data when it becomes available and the classification of <u>multi-date</u> Landsat imagery (several Landsat scenes acquired on different dates) for wildland vegetation mapping.

The objective of the 'normalization' experiment is to develop and demonstrate the best use of SI data (derived from DEMs) as applied to Landsat classification in wildland areas (specifically Mendocino County). Successful utilization of SI data in the classification of Landsat imagery could have substantial impact on overall user acceptance and the applications of Landsat products to wildland management decisions. Five areas where significant advantage may be achieved are listed below:

1. Increased Accuracy

   Since the effects of terrain will essentially be subtracted by application of SI data, we anticipate increased classification accuracy for many wildland applications. More accurate species

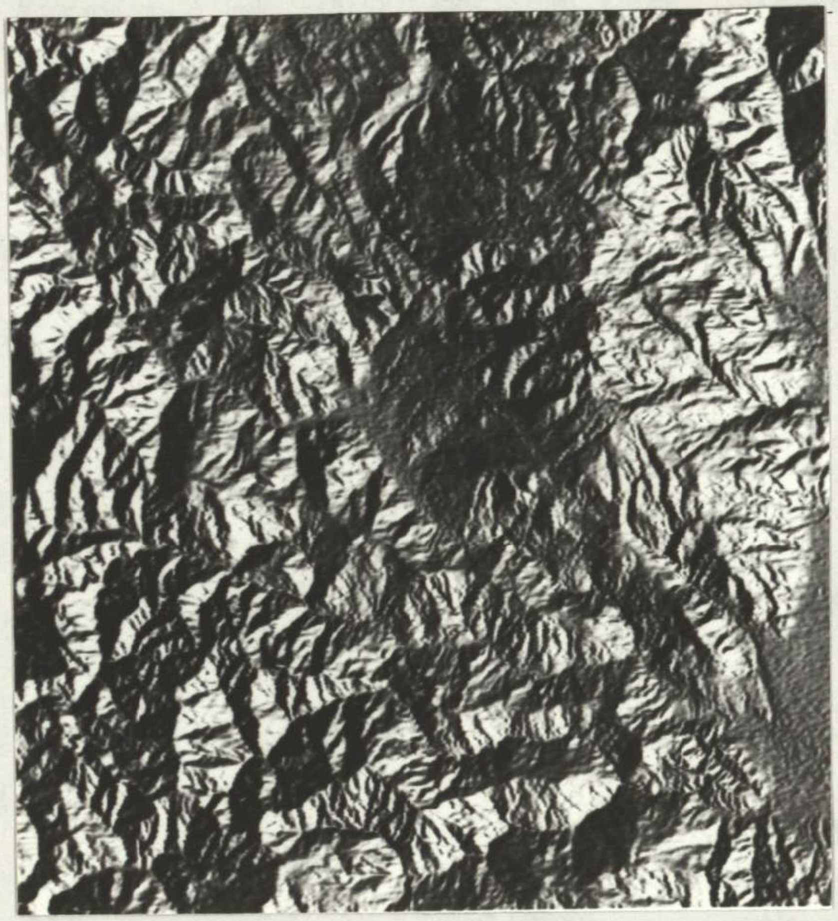

Figure 5. Solar Illumination (SI) band data simulates sunlight at the time of Landsat data acquisition. The resulting image is also a shaded relief map.

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composition, age class and stand condition estimates may be discernable from one, if not more, of the proposed test methodologies. If proven successful, SI applications to multi-date classifications could have definite impact on both woodland and rangeland classification accuracy.

SI utilization is anticipated to improve multi-date Landsat classification and open the door to wildland applications of processing methods now used exclusively for agricultural (flat land) classification (e.g. episodal event considerations, delta function stratification, GRABS, and other algorithms).

2. Increased Cost and Time Effectiveness

Since, in many of the proposed methodologies, the effects of terrain will be subtracted before classification, clustering algorithms should not require as many iterations before they can be used in making meaningful ground cover type separations. A reduction in the number of required iterations could offset the cost of SI data creation and data set formation.

Manual renumbering of classification output should be simplified since fewer classes will need to be grouped (renumbered). Users can spend their time assigning meaningful definitions to existent classes rather than determining the right groupings of 60+ classes.

3. Broadening User Base

Potential users from disciplines not yet attracted to Landsat capability may find simplified output products (i.e. fewer classes to renumber) easier to understand and use. Increased accuracy and reduced post-processing manipulations will simplify the task of communicating Landsat capability to non-technical and lay persons.

4. Integration Into Geographic Information Systems

Simplified and more accurate classification will enable geographic information systems to incorporate classified Landsat data for more varied and unforseen applications. The same classified map will easily be made applicable to fuel, range, forest and/or planning mapping needs by quickly combining a few, well defined ground cover classes.

5. Shaded Relief Map

User and public acceptance of Landsat and digital systems is greatly dependent upon their ability to visualize the natural resource situation. The shaded relief map, a by-product of the SI band, provides a quick way to portray terrain so that audiences can identify areas of interest and relate Landsat classifications and other products to the real world.

Sun azimuth and elevation values (annotated to every Landsat scene) have been mathematically combined with DEM elevation values to determine precise solar illumination (SI) values for each pixel at the time of Landsat data acquisition (see Figure 5).

Sunspect values that have been determined using minimal computer time, and initial comparisons with standard map products indicate a strong potential accuracy for the Sunspect mapping procedure. The procedure we have found most successful and with which the normalized image shown in Figure 6 was created is as follows:

1. Landsat Acquisition

2. Digital Elevation Model (DEM) acquisition

   $30m^2$ pixel size

   accurate to 14m (z axis)

   accuracy = or better than that of standard 7½' quad maps

3. Derivation of Slope and Aspect Values for each DEM pixel

   (See Appendix 1 to do this)

   normal unit vector determined to best fit plane

   we use 48 aspect values and compute slope in 1% increments

4. Determination of sun azimuth (degrees from North) and elevation (degrees above horizon) at time of Landsat acquisition

5. Slope, Aspect → Unit vector of pixel

   Sun Azimuth, Sun Elevation → Unit vector of sun position

   The inner product of the two unit vectors equals the relative direct solar illumination at the time of Landsat acquisition

   where S = Sunspect (solar illumination)

6. Since illumination of the ground cover is comprised of direct and indirect solar illumination (indirect illumination being caused primarily by diffuse skylight resulting from atmospheric attenuation) an additional component (constant) must be added to the SI band. The appropriate constant value (c) is determined by solving for minimum relative variance (coefficient of variation) for a variety of C values using a 1% sample of the Landsat scene or study area. The constant value deemed most

appropriate for inclusion in the normalization algorithm for each bend corresponds to the lowest value for the coefficient of variation curve (see Figure 6). The constant value is computed for each band and a new 'normalized' band created using:

$$\frac{L_i}{S + c} = N$$

where: L_i = raw Landsat value for band i

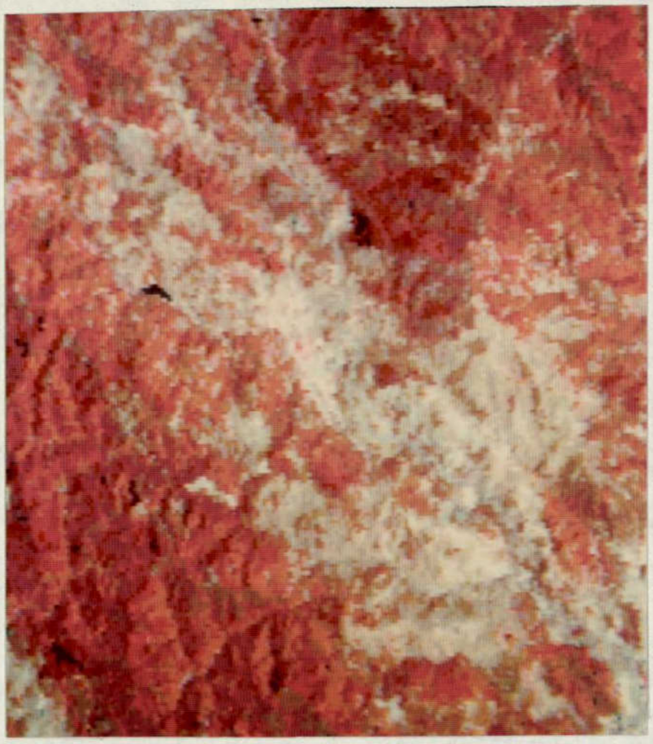
S = Solar Illumination (SI)

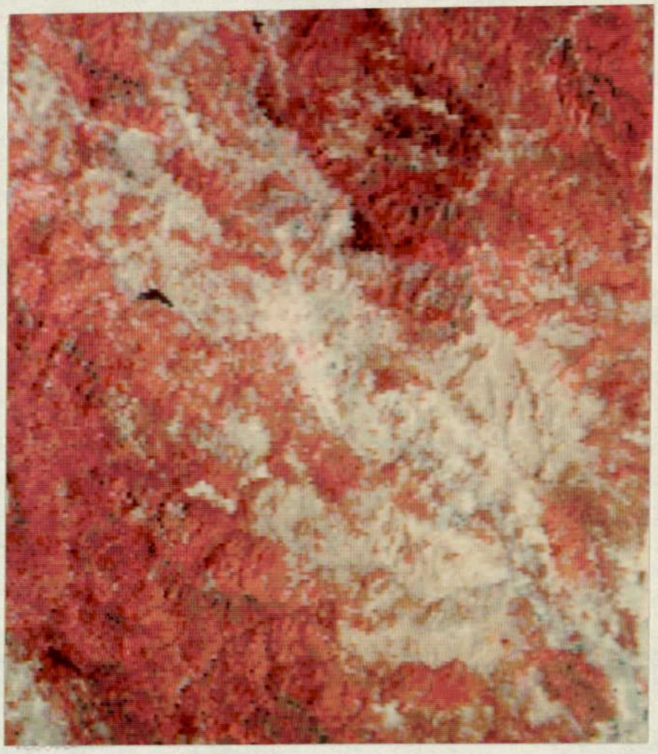
c = constant (for indirect solar illumination)

N = normalized band value

The graph plotted in Figure 7 shows the relative variance of two bands (MSS4 and MSS7) when the constant included in the normalizing algorithm is varied. The relative variance is defined as the coefficient of variation (CV) value which is the standard deviation of the data set sample divided by the mean $(\frac{SD}{\bar{x}})$. The constant value which is varied to determine the optimum value for normalization is described in step 6 in the procedure above. On the graph (Figure 7) the CV values for the raw data (no normalization) are also shown.

As indicated by this graph, the overall relative variance is decreased when the appropriate constant is selected for each band. The relative variance for normalized bands dips below the relative variance of the raw data. Using a 1% sample (as above) the appropriate constant





Landsat Raw Data
(False color image)

Normalized Landsat Data
(The effects of variable solar illumination 'subtracted')

Figure 6. The images above provide a comparison between raw data from the Landsat satellite and 'normalized' raw data which has been modeled to subtract the effects of variable solar illumination at the time of Landsat acquisition. Note that because of the $30m^2$ resolution of the DEM data the normalized image appears to have greater resolution than the raw data. By virute of this increased resolution the normalized image is also a simulation of what we can expect from data acquired by the Landsat 'D' Thematic Mapper when it becomes available.

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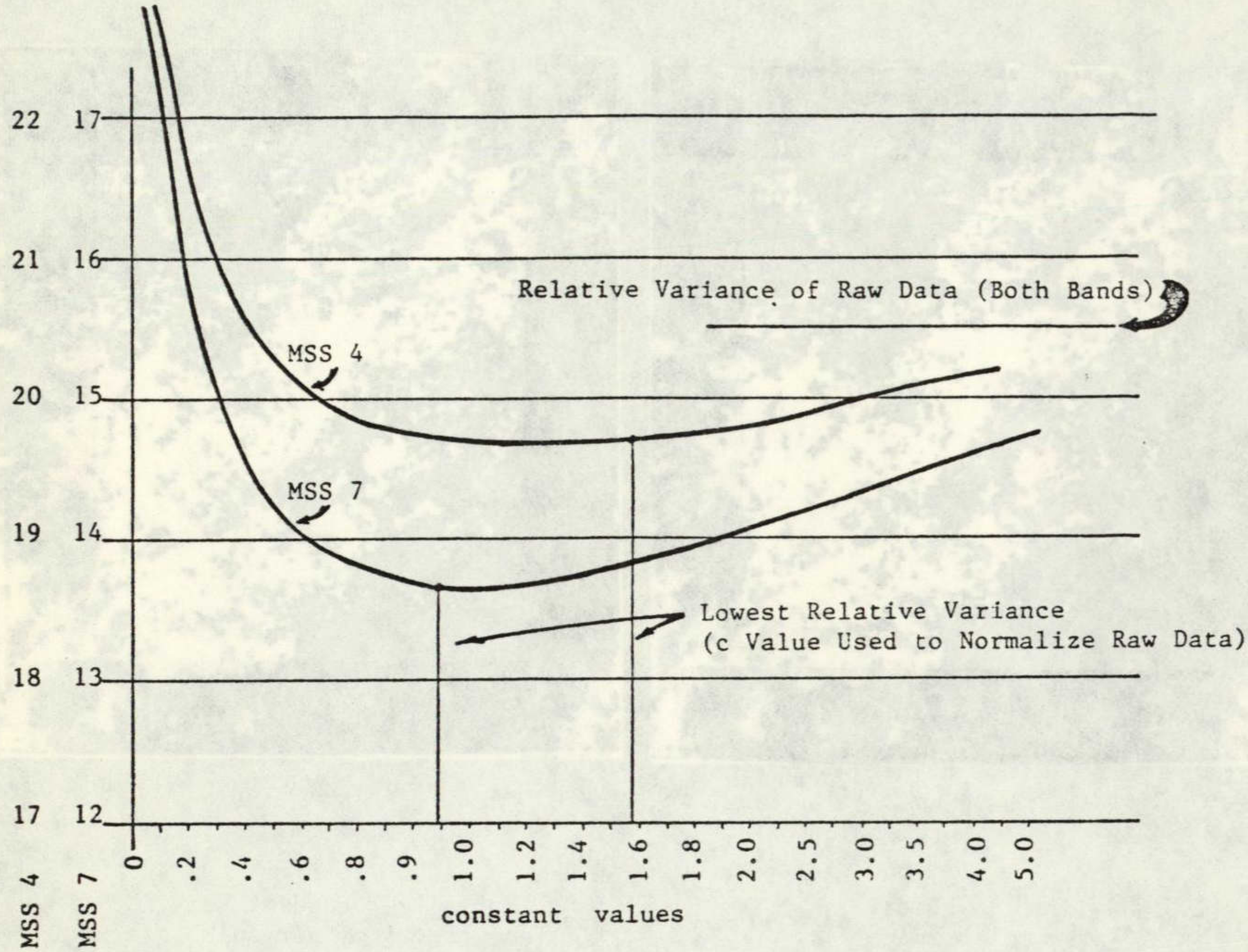

Figure 7. Relative variance (coefficient of variation or $\frac{SD}{\bar{x}}$) as constant value c increases (for 1% sample of MSS4 and MSS7). Note relative variance of raw data bands is much higher than normalized values.

values are chosen by selecting the constant value which decreases the CV (relative variance) the most. This value corresponds to the bottom of each curve in Figure 7. The effects of the normalization process on the accuracy of automatic Landsat data classification will be a major subject of next year's experimentation.

3.4 UTM Base Data Access System

In order to allow the resource system user to access exact positions on divergent types of maps with different coordinate and projection systems, a coordinate transfer mechanism is needed. For the Forsythe Experiment this need is satisfied by the creation of a system of coefficients that can transform a discrete coordinate pair, as read on one map projection, (e.g., USGS Digital Terrain Tapes) to the corresponding coordinate pair on any other projection (e.g., Landsat coordinates). This system enables Landsat data to be referenced to discrete elevations, slopes, soils, etc., for checking and testing accuracy; in addition, it allows final products to be accurately registered to a common Universal Transverse Mercator (UTM) coordinate system.

To achieve this coordinate transfer system the following two-phase procedure has been utilized (in this example for Landsat and Digital Terrain Data):

1. UTM coordinates of Landsat control pixels are determined from plots on orthophotoquad map sheets (visual selection of outstanding high contrast points on both Landsat and orthophotoquad images);
2. Regression algorithms are derived in order to determine the best fit of Landsat coordinates to UTM grid coordinates (<u>1st phase regression</u>);

3. UTM coordinates of Digital Terrain (USGS) control pixels are determined from plots on the USGS base map (1:24,000)(visual method as in Step 1);

4. Using first phase regression coefficients (Step 2), corresponding Landsat coordinates for digital terrain control points are determined;

5. A second phase regression algorithm is developed in order to determine the best fit of digital terrain coordinates to Landsat coordinates.

As new layers of information are added to the information system a series of regression coefficients will need to be established to determine the spatial relationship of one map level to another. Through use of the two phase regression procedure outlined above, this process will be simplified and made more accurate since the datum coordinates will first be tied to a common projection system (UTM) from which coordinates of any other map base can be determined (see Figure 8).

3.5 Base Map Compilation

In order to produce accurate positioning of all input data values to a common projection system a controlled base map has been compiled for Study Area 1. This map is derived from original USGS separates* at a scale of 1:24,000 and is virtually as accurate as the original manuscripts in that every reproduction from the original has been a contact exposure.

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*'separates' refers to a single-parameter original maps which are combined to create multi-data and multi-color maps. Examples include the drainage separate, land net separate and road separate.

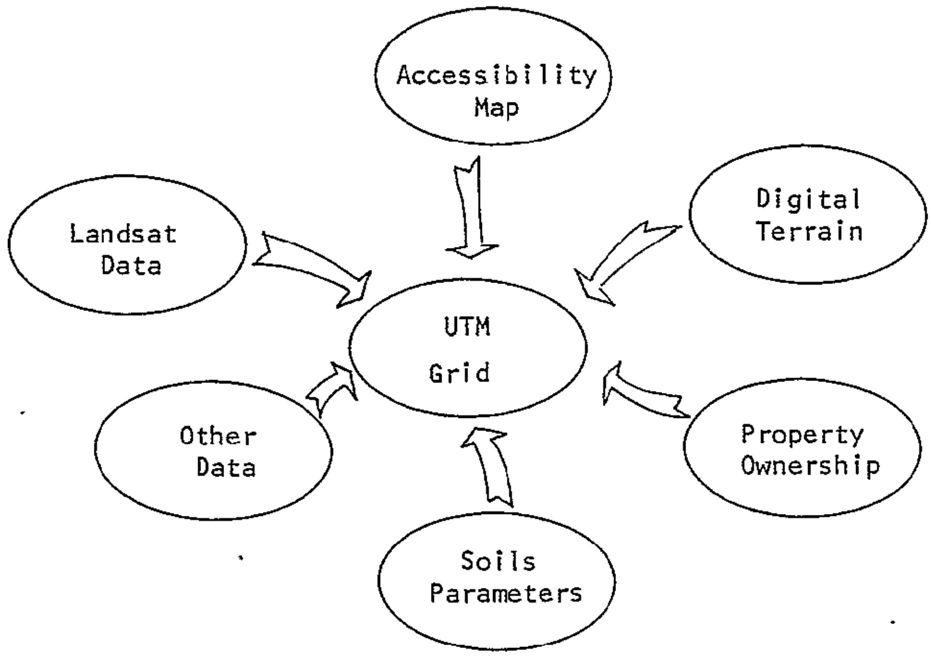


Figure 8. The spatial relationships among input data elements are connected by coefficients which tie each coordinate system to the UTM coordinate grid. This procedure has successfully integrated Landsat derived products into the current resource map base now utilized by both the California Department of Forestry and the Mendocino County Planning Department. Hard-copy products will be tied directly into the existent manual overlay systems of both agencies to demonstrate Landsat's usability as well as portability.

With the use of this control base map, digitized watershed boundaries, roads, property ownership boundaries, and the Universal Transverse Mercator Grid can be plotted to accurately represent ground positions in compliance with National Map Accuracy Standards. Further, adjacent quad maps will fit together with near absolute precision, thus avoiding variations in scale so common with paper map products.

Mendocino County is in the process of having every 7½' quad map in the County reproduced to the same specifications as the FPE base map. Final output products will match these maps and they will be incorporated into the County's mapping system.

An identical base map has been compiled for Study Area 2 which right registers to the County base maps and additionally to hardcopy products which will be forthcoming from the FPE. A hand processed orthophotoquad on stable matte mylar material has also been prepared and registered to the base. It forms the control for aerial photo interpretation and precision comparison with Landsat classifications.

3.6 Integration of Current Soils Survey

The Mendocino County Resource Conservation District and the U.S. Soil Conservation Service (SCS) jointly have been in the process of creating new soil data and a long range development program for natural resource conservation and development in Mendocino County.

The current survey represents the most comprehensive, thorough and accurate inventory of soils, soil potentials and soils limitations ever undertaken within the county. Through the assistance of the SCS Ukiah Office this data is being incorporated into the FPE demonstration project. Special thanks are due to the SCS mapping team for making unpublished soils data available. It should be noted that many of the soil attributes (e.g., site index) are not finalized in the unpublished manuscripts.

The job of integrating soils data into the planning process is the most difficult and the most essential. The potential for successful residential and other developments rests literally, as well as figuratively, on soil characteristics. Likewise the potential for timber regeneration and/or rangeland upgrading is determined more by the soil's characteristics than by any other single factor.

Incorporation of soils data into the FPE has involved the careful delineation of the most important soil characteristics for general and site-specific planning and resource management decisions. We have developed a list of soils attributes which meet the ultimate objectives of the demonstration without burdening the project with soils "data overload". These attributes include:

1. Hazard of Water Erosion (Very High, High, Moderate, Low and None).
2. Permeability (Fast, Moderately Fast, Moderate, Moderately Slow, Slow).
3. Available Water Capacity (inches).
4. Effective Rooting Depth (inches).
5. Runoff (High, Medium, Low).
6. Soil Suitability (Primary Suitability, i.e., residential development, grazing, firewood, timber, agriculture, recreation, watershed and wildlife habitat).
7. Site Index (timber soils only).

Soils, as they occur throughout much of Mendocino County, are intermingled and blend together forming gradations rather than distinct soils boundaries. Most soils (and/or soils veg maps)\portray soils as if they formed discrete and distinct units on the surface of the earth when, in reality, many soils cannot be distinctly separated. The current soils survey, used in the FPE demonstration, takes into account the gradient blending of soils,but, as will be seen, the increased accuracy of the new mapping causes the data to become more difficult to access and utilize.

To portray the soils accurately, (i.e. taking into account the gradient blending of soils types mentioned above) soils scientists in Mendocino County utilize the following procedure:

1. Using aerial photography, areas of similar vegetation and slope class are mapped. These areas, called <u>mapping units</u>, are the soils demarcations which appear on the final soils maps.
2. Ground surveys within each mapping unit are then performed to determine the discrete soil series (specific soils) which combine to make up the total soils within each mapping unit.
3. Each mapping unit is then described by the component soils listed by percent composition. Most mapping units (at least within the FPE study areas) are composed of two or three different soils series with one or two minor soils (called inclusions) which comprise 25% or less of the total mapping area.

As a result of this procedure, the soils map user does not know where any particular soils series can be found. This makes site-specific soil assessment very difficult since the data user has only a 'probability' of finding a given soil at a given site.

Working with SCS soils scientists we have developed a working methodology to apply the soils data to site-specific planning needs of the demonstration project despite the probabilistic nature of the data as described above.

To simplify the soils data, a matrix or cross-reference chart is being made to evaluate each mapping unit by its soils attributes. For example, if it is found that the #139 Bearwallow-Hellman complex mapping unit has a water erosion hazard rating of moderate/high for Bearwallow soil and moderate/high for Hellman soil, then we can evaluate the entire mapping unit as having a "Hazard of Water Erosion" rating of moderate/high.

Upon evaluating the mapping units in Study Area 2 it is clear that most of the primary attributes for the soils within a given mapping unit are the same. Thus it is an easy task to utilize the computer display capability to create a map of "Hazard of Water Erosion" that is very accurate and, at the same time, easy for the planner or resource manager to access and comprehend.

In those instances where a particular attribute varies for the soils within a mapping unit, the values will be proportionately averaged to give one value for the entire mapping unit.

Because of the entering of soils data, including the averaged soil attributes, into the interactive system, the user can access and comprehend a soils attribute map much more readily than by using the soils map itself and he is spared the time consuming process of decoding the soils information so that it can be used.

In this regard the success of the overall demonstration will ultimately depend on the advantage over manual methods that can be demonstrated to the real potential users. The 'de-coding' of soils data is a key to the demonstration and with the continued assistance of the SCS and the soils conservation district we will have a strong soils component in the demonstration.

4.0 Work in Progress

4.1 Vegetation Classification

Now that a normalized Landsat data set has been created using Solar Illumination models to correct for variable illumination of the study area terrain, we will evaluate the product by utilizing a supervised computer classification to isolate classes of spectral similarity for the Willits SE quad (Study Area 2). Staff from the County Planning Department, the Soil Survey team, and the California Department of Forestry will be invited to an evaluation and vegetation class assignment session. As a control, a supervised classification of the original raw data will be performed and the outcome compared with the classified normalized bands.

4.2 Completion of Demonstration Geographic Information System (GIS)

The resource data set currently being built will be completed and evaluated by RSRP staff and also by the potential user community in Mendocino County.

The expected components of the base line data set being built for each study area are listed in Appendix 2.

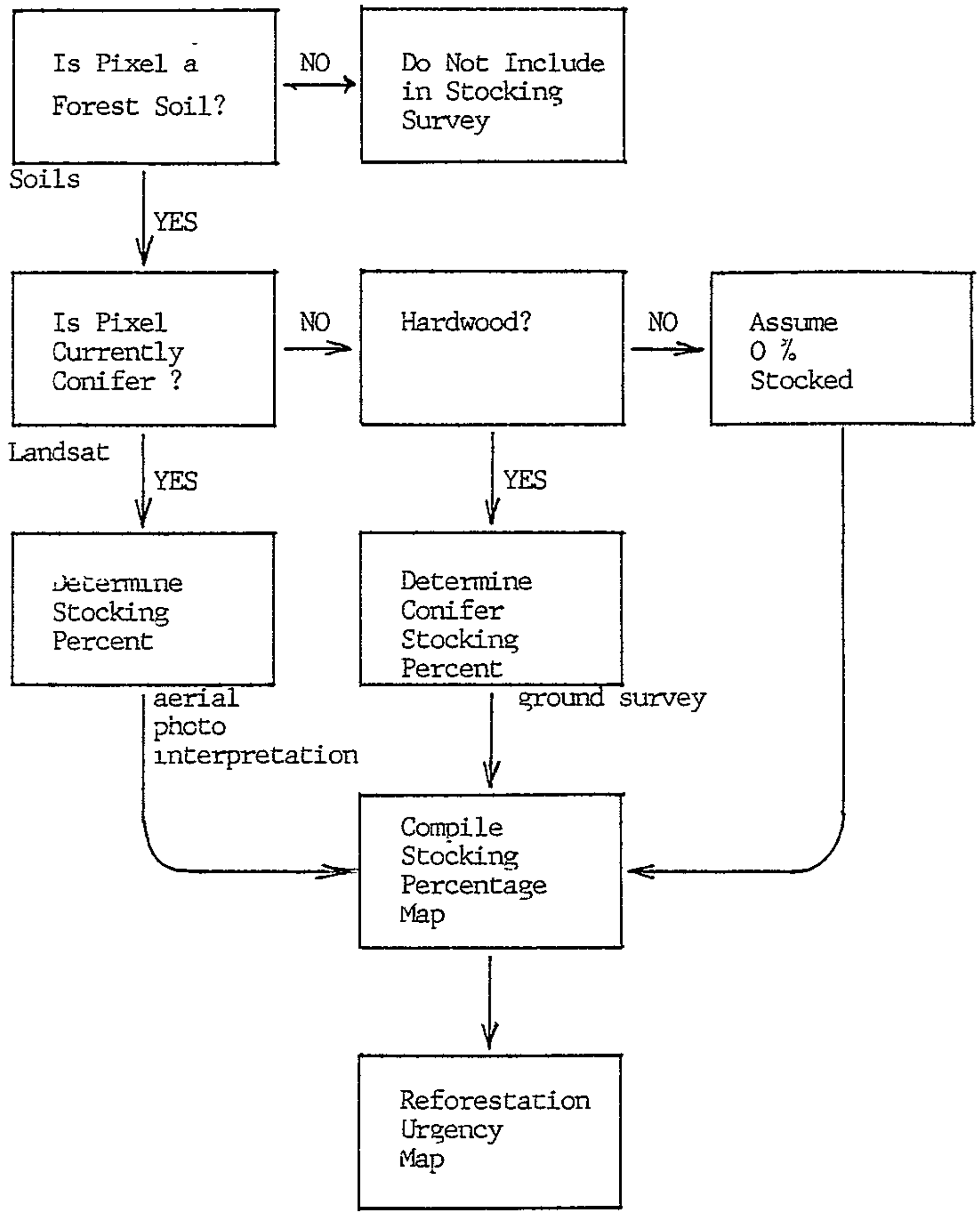
4.3 System Utilization

The advantages of the interactive information systems being built will result from the users' ability to model the base line data into new data types. Utilizing the data in an interactive mode, planners and resource managers will have the opportunity to overlay data bands, perform band combinations and models using the data set and introduced ancillary data.

A simple example will be the isolation of flammable brush types (derived from Landsat) combined with a slope map overlay. In this example the system user will be able not only to isolate flammable brush but also to analyze the slope severity of the brush class and quickly assign specific firebreak construction techniques (i.e., mechanical, chemical, biological or control burning). Previously, brush managers have had to rely on tedious manual mapping processes to derive the same essential information.

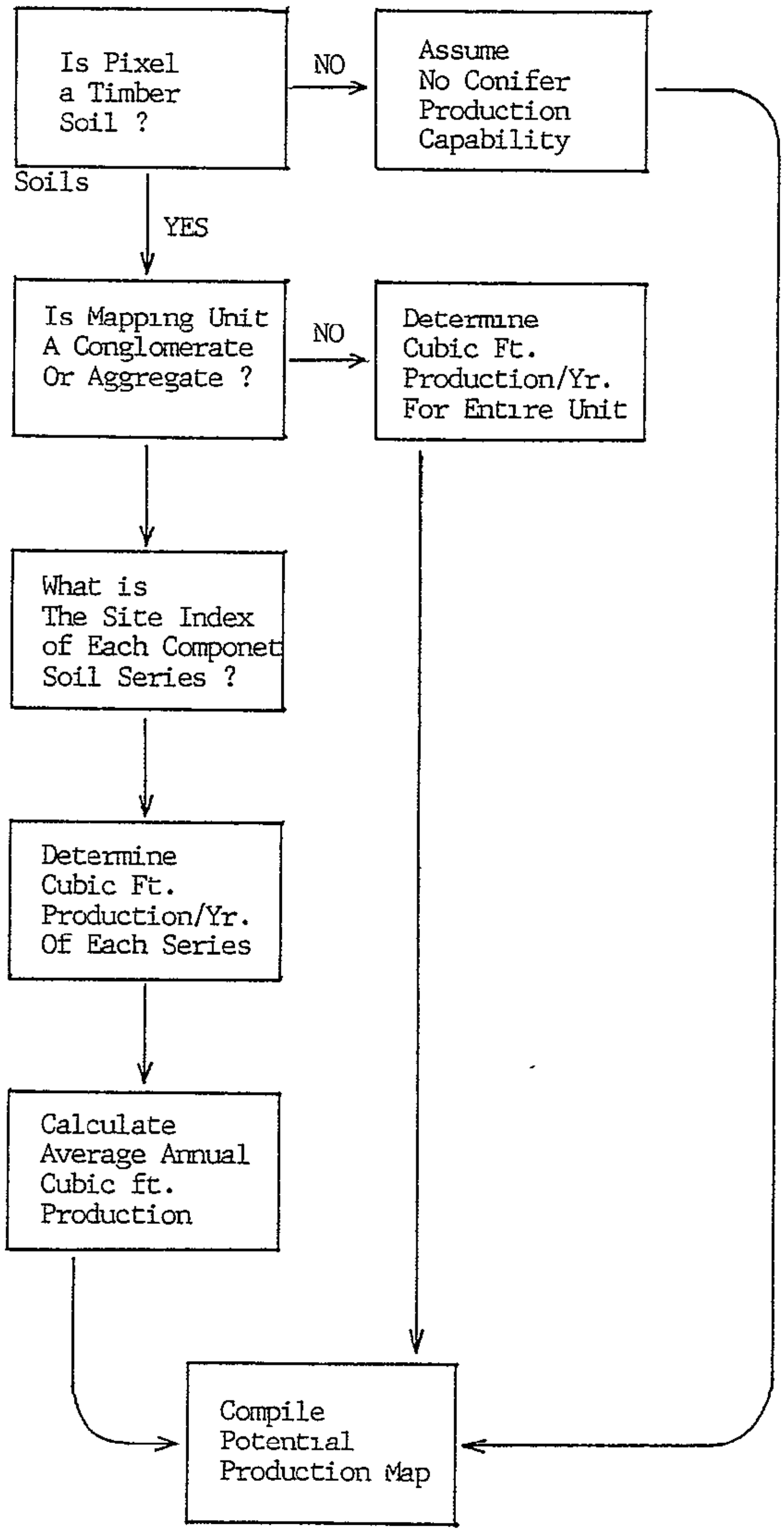
Apart from the simple example above the system's capability will also embrace the potential for spatial modeling. Modeling techniques will bring several data levels together to interact in a mathematically defined way to yield useful information virtually unattainable by conventional manual methods.

Several flow charts are presented in Figures 9, 10, 11, 12, and 13 to show the proposed modeling of the data set which RSRP specialists and SCS researchers and foresters have developed. Each will entail careful attention to geometric accuracy and data fidelity. In this regard the importance of accurate registration, reformatting, and original map accuracy cannot be over-emphasized. The modeling processes graphically illustrated below are currently being evaluated by county and University foresters and geographers, and will undoubtedly undergo modifications and substantial changes prior to their implementation.



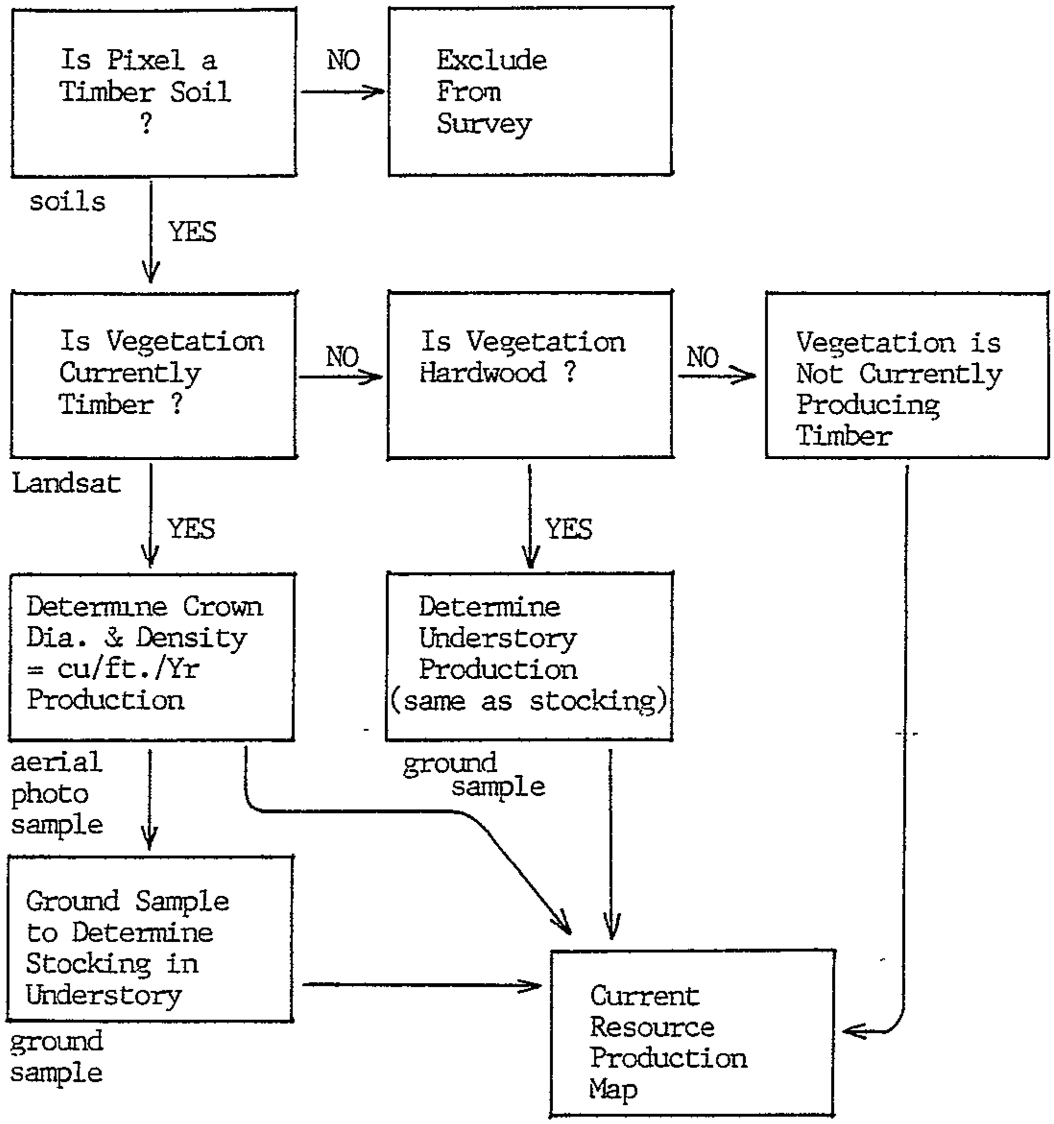
4.3.1

Figure 9. Flow Chart for producing a "Percent Stocking" Map



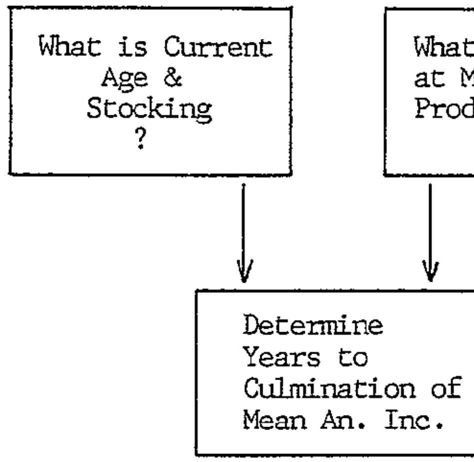
4.3.2

Figure 10. Flow Chart for use in producing a map of "Potential Resource Production" (at Culmination of Mean Annual Increment)



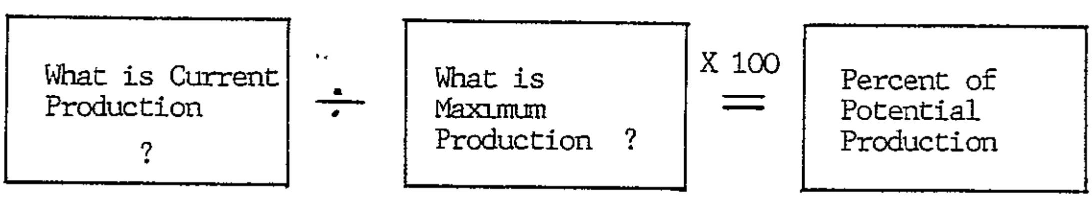
4.3.3

Figure 11. Flow Chart for producing a map of "Current Resource Production"



4.3.4

Figure 12. Procedure for determining "Years to Culmination of Mean Annual Increment"



4.3.5

Figure 13. Procedure for determining "Current Production Expressed as a Percent of Potential Production"

5.0 Summary and Conclusion

The Forsythe Planning Experiment is now in its tenth month. Progress to date has included the delineation of project goals with participating agencies, the construction of data sets to meet these goals, the formulation of demonstration tasks within the constraints of two Geographic Information Systems, and the utilization of elevation data to normalize raw Landsat data in an effort to correct for the variability caused by solar illumination. All of these topics have been addressed specifically in this report.

We have called this project an experiment because it involves the testing of specific hypotheses (e.g., solar illumination normalization), and the evaluation of existing data, inside the constraints of an interactive computer environment. Beyond the experimentation, the FPE is a demonstration of existing technologies which have been successfully incorporated into planning and resource management processes in other areas in an operational mode. As computer hardware costs continue to drop, the capabilities we are demonstrating will come closer to actualization in Mendocino County and other rural areas. By successfully demonstrating the capabilities of computer-based geographic information systems and satellite resource applications, we are in the process of hastening the day when full commitment to an operational remote sensing-based interactive system on the part of many users at the county level, will have been made.

To this end, the use of spurious, inaccurate and imprecise data must be carefully avoided. If, in attempting to demonstrate the capabilities of "the systems approach", we create inaccurate and unusable products we will in effect demonstrate only failure and will inadvertently add evidence for use by detractors of the concept that modern remote sensing technology should be applied to resource management problems. For example, the use of inaccurate Digital Terrain Tape (DTT) elevation data, as described in section 3.1, could ruin the demonstration. An inaccurate map, or an inaccurate GIS, is worse than none. In this respect we have taken special care and time to assure the accuracy of the final products.

With respect ot Landsat utilization, the detailed resolution and site-specific requirements that need to be satisfied are such that they will tax the capacity of Landsat to the limit. For the potential users the limits of Landsat will be thoroughly demonstrated. In this regard we have made no promises, noting severe problems that can be associated with 1.1 acre resolution, and the need for increased scanner resolution on future resource satellites (NOAA, 1980). The normalization procedure outlined in section 3.3 will hopefully extend the usefulness of Landsat for wildland applications, but the strongest promise must lie in the higher resolution thematic mapper of Landsat 'D' or the higher resolution of certain other earth satellite systems, should they become operational and/or accessible before Landsat.

Specific applications of the data set and the GIS systems we are using will be discussed more thoroughly in this project's final report although, even then, it may be difficult to predict all of the long-term benefits that can be achieved as a result of this demonstration. The real outcome will be determined by the eventual utilization of our efforts, whether this occurs now or in the future. The project has, understandably, been greeted by the potential users in Mendocino County with skepticism and watchful caution, despite their willingness to contribute sizable amounts of support to it. Whether this skepticism will delay the utilization of the GIS output is impossible to predict, but it is perhaps a note of good fortune because, if enthusiasm for the project had been unduly high at the outset, the probability of disillusionment would have been much higher and the subsequent rebuilding of confidence would have taken much longer. Through the continued support and involvement of key personnel within Mendocino County we look forward to a productive conclusion to this demonstration and to the successful integration and utilization of several remote sensing-derived GIS output products as essential aids to the making of specific planning decisions within the study areas.

6.0 Literature Cited

1. Benson, A.S., L.H. Beck and C.E. Henderson, 1979. Fuel Mapping in Relation to the Management of Brushlands and Timberlands in California. Application of Remote Sensing to Selected Problems Within the State of California

2. Hancock, D., D.R. Dotters and W.W. Randolph, 1977. Land Use Study for Economic/Employment Impact, Mendocino County.

3. Mendocino County General Plan/E.I.R. Draft, 1980. Mendocino County Planning Department.

4. National Cartographic Information Center, Digital Terrain Tapes. NCIC User Guide, Geological Survey, U.S. Department of the Interior.

7.0 Appendix 1. Solar Illumination Modeling Variables

Solar Illumination (SI) is being computed from slope and aspect bands derived from the elevation data for Digital Elevation Models (DEM). Results indicate that it is necessary to consider light scattering by the atmosphere as well as direct sunlight in developing a satisfactory SI model. It is necessary to use different parameters in the SI model for the four MSS bands because of the different scattering properties of light at various wavelengths.

The following is a brief discussion of each of the variables involved in accurate solar illumination modeling.

1. Sun Azimuth and Elevation at Time of Landsat Data Acquisition (Position of Light Source)

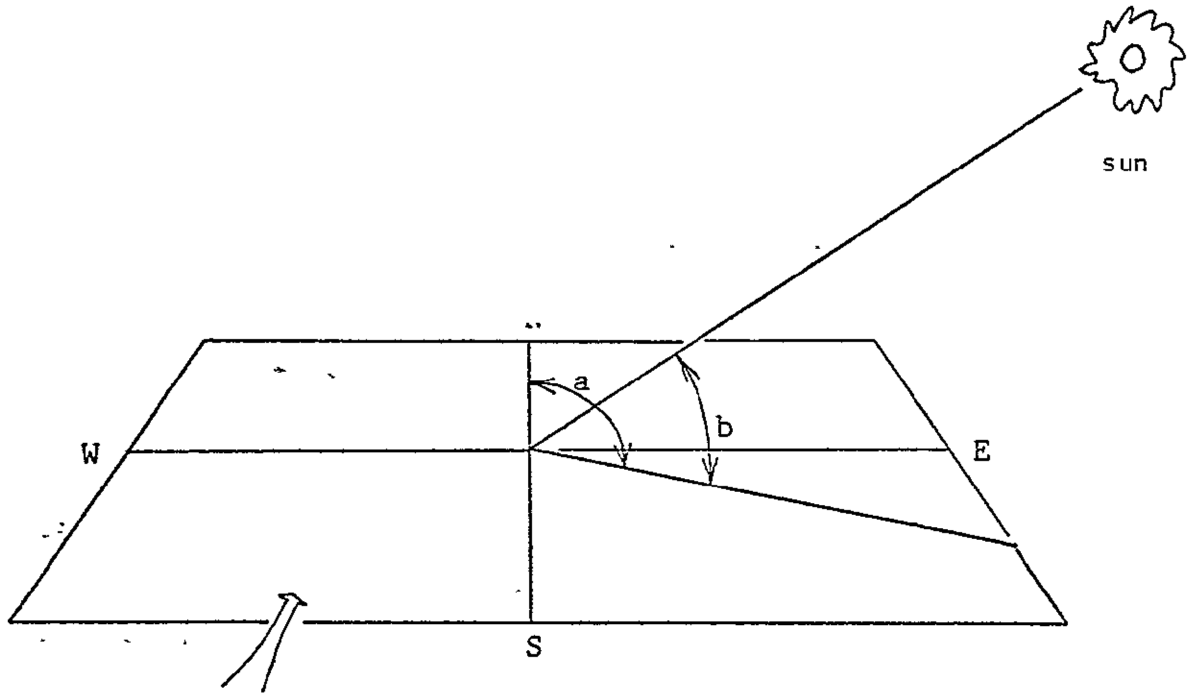
   Landsat is a passive data collection device in that it uses light from the sun as its source for ground illumination. The position of the sun with respect to the ground surface is the primary determinant of the illumination for each pixel. Sun azimuth (angle from true North) and elevation (angle from horizon) are annotated on each Landsat scene by the EROS Data Center (see Figure 14).

2. Slope and Aspect Value of Each Pixel

   Slope is defined as the degree a surface deviates from level. Slope is expressed in percent, 100% equals a slope of 45°.

   Aspect is defined as the compass direction in which a sloping surface faces and is usually measured in degrees clockwise from true north.

   The slope and aspect values for any one pixel are determined



Landsat Scene

a = azimuth (angle from true north)

b = elevation (angle above horizon)

Figure 14. The diagram above shows how sun position relative to a Landsat scene is described by azimuth and elevation values.

by the elevation values of the four immediately adjacent pixels (see Figure 15). The algorithm used at RSRP examines the elevation values for each of the four pixels surrounding a pixel in question and calculates a normal vector representing a plane which will best fit the four elevations. The coordinate values for the normal vector are then translated into degree values for slope and aspect and assigned to the pixel in question (see Figure 15).

3. Direct Solar Illumination (angular orientation of illuminated surface to light source)

   The relationship of the best fitting plane (slope and aspect) to the azimuth and elevation of the sun reveals the <u>direct solar illumination</u> for each pixel. This direct solar illumination component of total solar illumination is proportional to the cosine of the angle between the sun and the normal vector to the surface. This can be computed as the inner product of a unit vector in the direction of the sun and a unit vector normal to the surface. If the cosine is negative, the surface receives no direct sunlight.

4. Indirect Solar Illumination (Rayleigh Scattering)

   Gas particles in the atmosphere scatter light proportionately to $1/\lambda^4$ where λ = wavelength. Thus, blue light (short wavelength) is scattered far more than red light (long wavelength). As a result of this differential scattering of blue light, (called Rayleigh scattering) the sky appears blue.

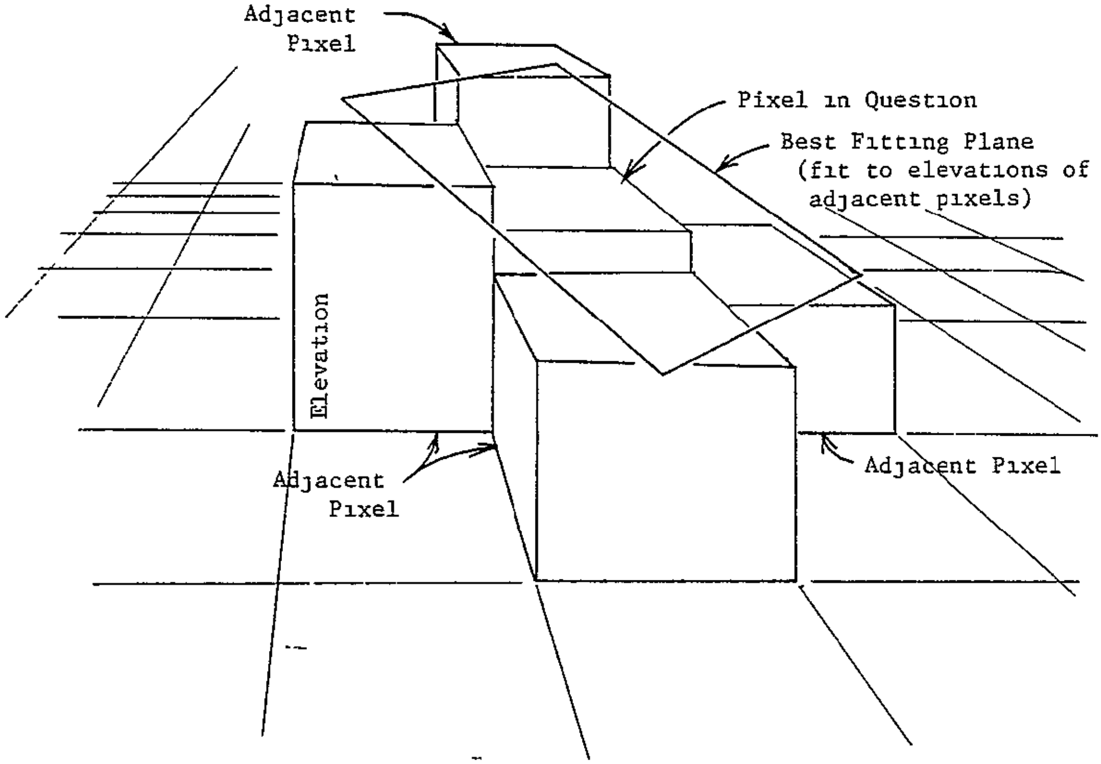


Figure 15. Determination of Slope and Aspect from Elevation Data. Slope and Aspect of Best Fitting Plane assigned to Pixel in Question

Blue scattered light accounts for most of the shadow illumination and is an important illumination component for surfaces which receive a minumum of direct solar illumination (see 3).

Computing the component of SI due to scattered light will require some additional research. As a first approximation, we could consider the sky to be a uniformly illuminated hemisphere. Then if θ is the angle of the sloping surface to the horizontal (i.e., angle between a vector to the normal surface and the vertical), this component would be proportional to $(180° - \theta)$.

Total solar illumination must equal the sum of direct + indirect illumination values and will vary for each Landsat spectral band due to selective (Rayleigh) scattering.

5. Possible Shadow from Nearby Pixels

In steep terrain, and at Landsat acquisition nearer the winter solstice (low sun angle), shadows from mountain peaks and ridges will cover lower areas in valleys and depressions.

Pixels in shadow can be calculated using a convolution type comparator algorithm which will track from the pixel in question "n" pixels in the azimuth direction of the sun. Elevation values for each pixel encountered will be compared with the elevation value of the pixel in question; angular relationships will then be determined and compared with sun elevation. If values are greater than sun elevation, the pixel in question is in shadow and will be automatically assigned to a separate shadow class.*

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*A spin-off of development of a shadow determination algorithm will be the capability to accurately assess total potential solar insolation (available solar energy) on a yearly (or seasonal) basis for large tracts of land. An 'available solar energy map' could then be created by subtracting average cloud cover information from the 'potential solar insolation product'.

An available solar energy map could have significant value to reforestation, wildlife habitat mapping, ecological research, land development, solar energy collection, and many other types of activity.

8.0 Appendix 2

OUTPUT PRODUCTS FOR EACH STUDY AREA

<u>Study Area 1</u>

	In System
Landsat Raw Data (June 27, 1976)	x
DTT Elevation (40' contour intervals)	x
DTT Slope (10% slope classes)	x
DTT Aspect (7.5° aspect classes)	x
DTT Renumbered Aspect	x
DTT Solar Illumination (SI)	x
Landsat Normalized Data (using SI from DTT)	

<u>Study Area 2</u>

Data Base	In System
Landsat Raw Data (June 27, 1976)	x
DEM Elevation (10m contour intervals)	x
DEM Elevation (40m contour intervals)	x
DEM Slope (1% slope classes)	x
DEM Aspect (7.5° aspect classes)	x
DEM Renumbered Aspect	x
DEM Solar Illumination (SI)	x
Landsat Normalized Data (using SI from DEM)	x
Vegetation/Land Use Map	
Soil Mapping Units	
Hazard of Water Erosion	
Permeability	
Available Water Capacity	
Effective Rooting Depth	
Runoff	
Soil Suitability	
Site-Index (timber soils only)	

Derived Products

- Percent Timber Stocking Map
- Potential Timber Resource Production Map
- Current Timber Resource Production Map
- Years to Culmination of Mean Annual Increment Map
- Current Production Expressed as a Percent of Potential Production Map

Study Area 3 (Landpak System)

Data Base

Landsat Vegetation/Land Use Map
DEM Elevation (40' contour intervals)
DEM Slope
DEM Aspect
DEM Solar Illumination
Soil Mapping Units
Hazard of Water Erosion
Permeability
Available Water Capacity
Effective Rooting Depth
Runoff
Soil Suitability
Site Index

Property Ownership Boundaries
Legal Owner
Zoning
Preserve Status
Mineral Rights Owner
Timber Rights Owner
Legal Description
Logging History (if available)
Assessed Value

Roads (condition)
Power Lines
Septic Systems
Fire History

Percent Timber Stocking Map
Potential Timber Resource Production Map
Current Timber Resource Production Map
Years to Culmination of Mean Annual Increment Map
Current Production Expressed as a Percent of
  Potential Production Map
Others to be determined

PART III

APPLICATION OF CALIFORNIA'S STATEWIDE LANDSAT DATA SET TO COORDINATED RESOURCE PLANNING IN COLUSA COUNTY

by

Louisa H. Beck

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EXECUTIVE SUMMARY

This report describes the application of satellite-derived information to Coordinated Resource Planning in Colusa County, northern California.* Personnel from the Remote Sensing Research Program (RSRP), University of California, Berkeley, have been working closely with personnel from the Stonyford Resource Conservation District in order to apply this information to the following management goals:

(1) acquaint the members of the Stonyford Resource Conservation District with the potential uses of satellite-derived information as input to the Coordinated Resource Plan for the Grapevine area;

(2) explore the feasibility of a satellite-based information system for this relatively small area (43,000 acres);

(3) develop a methodology whereby general vegetation classes of primary interest could be refined to provide more detailed and meaningful classes for resource management; and

(4) ensure the use of the refined satellite-derived information by resource managers in Colusa County as they formulate and implement various resource management decisions.

The primary data being used to meet these goals are portions of a state-wide digital Landsat data set developed for the California Department

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*Coordinated Resource Planning is the term applied to certain cooperative efforts of land owners and public agencies in order to improve the management of the land and its resources in a given geographic area. CRP is mandated by the 1975 Memorandum of Understanding (Appendix A).

of Forestry which includes both raw and classified digital data. Secondary data sets include small-scale aerial photography and digital terrain data.

1.0 Introduction

1.1 Historic Background

Coordinated Resource Planning is a process that depends upon the cooperative efforts of land owners and public agencies in order to improve the management of the land and its resources in a given area. This process has many positive aspects:

1. Cooperative planning avoids duplicative and/or conflicting actions between neighboring land owners, and provides far more comprehensive and efficient management.
2. This comprehensive approach reduces the chance of overlooking potential multiple use benefits.
3. The cooperative nature of the process provides for private as well as public agency input into land managment actions, making this type of planning a participatory and educational process.
4. Building upon (3), the interchange between public agencies and the private owners provides a base of understanding, so that the agencies are cognizant of the ranchers' (owners') needs, while the ranchers may come to understand why some seemingly valuable ideas cannot be implemented.

The process itself utilizes the combined knowledge and expertise special to each of the concerned participants. After establishing a committee, the participants, as a group, inventory the area of concern, analyze the data, identify and agree upon common management objectives, and then evaluate and select among the various alternatives in order to achieve those goals. The alternatives chosen will depend not only on the goals of the group, but on their combined expertise as well. By this approach, the committee structures its management alternatives in accordance with both the resource base itself and the mutual objectives of the group. It also takes into account the dynamic nature of the land resource, as the committee meets on a regular basis in order to monitor all actions and to amend any portion of the coordinated resource plan.

In this fashion, Coordinated Resource Planning can combine the goals of many owners and public agencies into a more efficient and responsive management scheme, thus maximizing multiple use benefits with limited monetary funds. It also assures that no single agency is responsible for all land use planning efforts.

It is necessary for coordinated planning committees to acquire and analyze timely inventory data, and to evaluate the impact and cost-effectiveness of each feasible management action of proposed land use. Although expenses are shared between private owners and public agencies, the extensive data requirements still make it difficult for responsible groups to keep up with the dynamic nature of the environment. In Colusa County, the Stonyford Resource Conservation District (RCD) is a group that realizes dynamic changes are occurring, and not all for the good: large stands of decadent chamise have been encroaching on neighboring agricultural areas, resulting in reduction of rangeland and productive ecotone environments for wildlife. The increasing brush has also affected water yield, and poses a considerable fire danger to both wildlife and commercial activities in the area.

In 1977, the Stonyford RCD initiated the Grapevine Coordinated Resource Plan. (See Figure 1 for the location of the Grapevine study area in Colusa County.) The purpose of the plan was to address the concerns expressed above. The agencies involved included the California Department of Forestry (CDF), California Department of Fish and Game (CDFG), USDA Soil Conservation Service (SCS), USDA Forest Service, USDA Agricultural Stabilization and Conservation Service (ASCS), UC Cooperative Extension Service, and USDI Bureau of Land Management (BLM). Cooperating with these public agencies are 27 private land owners, the Colusa County Board of Supervisors, and the Indian Valley Fire Protection District.

Each group's concern stems in part from the extensive and continuous stands of decadent chamise located along the ridges of the Grapevine area. Although this brush represents many potential impacts for the area (lower water yield, reduced wildlife and domestic forage, etc.), the primary concern is that the continuous coverage of chamise in many areas could result in very extensive impact on the area should a fire start. The resulting loss of plant cover would create serious erosion problems on the upland soils, and eventually bring about serious sedimentation problems in the productive alluvial valleys below. This would have severe repercussions on wildlife habitat and on agricultural activities in the resource district.

To manage the Grapevine area and to achieve the RCD's planning goals, the RCD committee has had to collect extensive data on the areal extent of brush, as well as information concerning stand condition, soils, slope, and surrounding vegetation conditions. Unfortunately, the majority of the Grapevine area is roadless. Slopes in the area are generally steep,

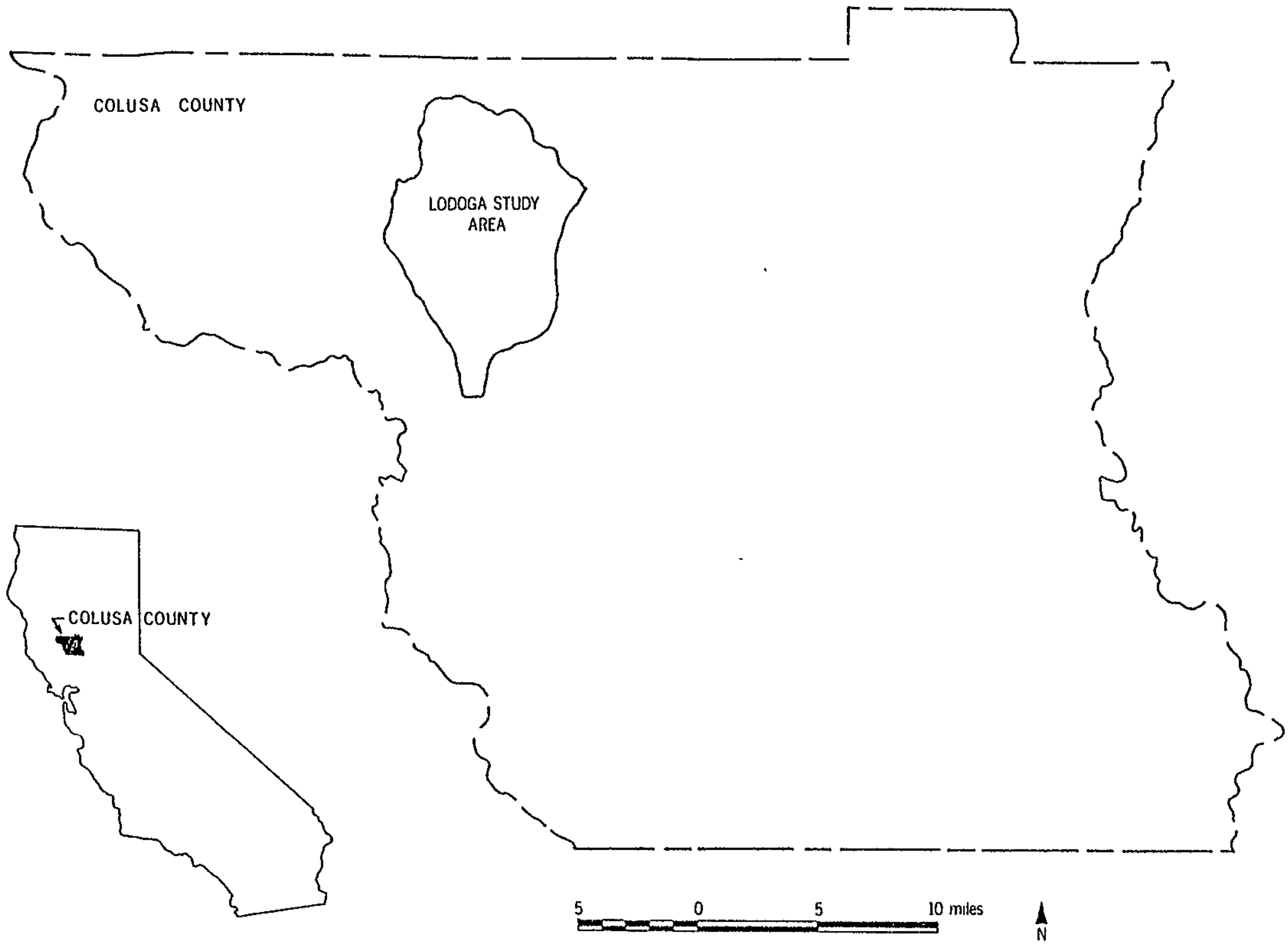

Figure 1. Location of Grapevine study area in Colusa County, California.

and soils are susceptible to erosion and damage from vehicular use. Yet some timely and cost-effective method for collecting data was needed so that the RCD committee could make specific management recommendations for the resource district. This method had to be comprehensive and provide for ongoing input, so that an accurate inventory base could be maintained.

Towards this end, the RCD committee has been considering the value of remotely-sensed data. The first demonstration of remote sensing applications in the Stonyford RCD came in June, 1978, when personnel of UC's Remote Sensing Research Program (RSRP) provided the personnel of the Colusa Field Office of the SCS with training in the use of high-flight infrared photography as a tool for resource inventory. Largely because of this training, SCS personnel were able to locate 100 new spring sites within the Grapevine area using U-2 infrared imagery. The discovery of these spring sites has aided ranchers in the area by facilitating the location of cattle watering ponds. By the use of small-scale photography, SCS personnel were thus able to inexpensively and quickly locate a resource that would have taken many months of arduous field work.

The goals of the Grapevine Coordinated Resource Plan require much data that would be both expensive and laborious to collect in the field, as well as difficult to correlate and combine into a useful format for resource management applications. Added to the problems associated with developing a voluminous data base, the density and extent of the brush community makes access to the information needed for brush management nearly impossible.

Because of the quantity of the data needed, and the impenetrable nature of the brush community, certain members of the RCD committee felt that some system of remotely-sensed data would be desirable to provide their information needs. Rather than digitize soils, vegetation, and terrain information from U-2 imagery and topographic sheets, however, the SCS personnel turned to UC Berkeley's RSRP for help in developing and organizing a Landsat-based data set for the Grapevine area. Landsat data was chosen because the digital format makes a useful data base upon which to build; and, when combined with other forms of ancillary data, (e.g., digital terrain), provides a solid data set with which to achieve the RCD's objectives.

Last year, personnel from the RSRP demonstrated that the application of remote sensing-derived information, and its associated technology, could provide a cost-effective means for inventorying and analyzing large areas for resource planning in Mendocino County (Benson and Beck, 1979). Although that study was conducted for a much larger area, some of the goals of the RCD plan could be realized in the 43,000-acre site using Landsat-derived data and technology, with appropriate modifications.

1.2 Objectives

The objectives of this project were fourfold. Our primary goal was to acquaint the Stonyford RCD committee and other potential users with satellite-derived information as input to the planning process. As the committee consists of representatives of various State and federal agencies, this small demonstration would expand the knowledge of remote sensing techniques to other agencies. The second objective was to investigate the application of digitally-mosaicked Landsat data for Coordinated

Resource Planning in a relatively small wildland area. As Coordinated Resource Planning is generally limited to more localized areas, we felt it necessary to investigate the accuracy and feasibility of satellite-derived data systems for the smaller wildland area. This objective has application beyond Coordinated Resource Planning in that many federal and State agencies administer small holdings that are not currently considered feasible for spacecraft remote sensing applications.

The third objective was to develop a methodology whereby CDF-defined vegetation classes could be refined to more meaningful classes for brush management purposes. This idea was based on the SCS' desire to separate the more decadent stands of chamise from the younger and less flammable stands. If a correlation could be found between spectral characteristics and age class/stand condition, substantial advances in current Landsat applications in California's wildlands could occur.

The fourth objective of this project was to promote use of the refined satellite-derived information by resource managers in Colusa County for formulating and implementing various resource management decisions of the RCD plan. Use of this type of data should assist in the efficient allocation of management personnel and resources. As areas of concern for fuel management are located on the image product, both terrain and acreage information can be derived from the data set that would expedite management activities.

1.3 The Data Set

The basic data set used to accomplish the objectives of the project was to consist of raw and classified Landsat digital data (CDF data set). This set would then be combined with ancillary data that would include high-flight photography, USGS orthophoto coverage, and digital terrain information. By combining the digital spectral data with the digital terrain data, creation of a data set enabling a user to determine areal extent of vegetation types as well as the topographic characteristics associated with them would be possible. The spectral data, when used in conjunction with terrain information, could provide the committee with information useful for a multiplicity of purposes. The data set would organize several levels of information efficiently, and would be available for use on a real-time basis as well as for data bank applications.

Depending on the intended purpose, a user could combine various levels of data: initially, a simple vegetation map could be produced, while as the data base is expanded, a user might be able to produce maps depicting wind direction, slope, and vegetation type in order to predict expected rate and direction of fire spread in a given area.

1.3.1 The CDF Data Set

The primary Landsat data set that was used to meet the objectives of this project covered the 1° x 1° Ukiah East quadrangle. The quadrangle was part of the data set developed by the Jet Propulsion Laboratory (JPL), Pasadena, California, and NASA-Ames Research Center, Moffett Field, California, for the California Department of Forestry. Essentially, Landsat-1 scenes from August 1976 covering the entire State were digitally mosaicked together, resampled to produce 80-meter^2 pixels, and registered to a Lambert Conic Conformal projection (Newland, Peterson, and Norman, 1980). The spectral data set consisted of four bands of raw Landsat data and a fifth band of classified data. The fifth band represented the unsupervised classification of the first four bands, which resulted in the grouping of the raw spectral data into clusters of data with similar spectral brightness values. Each cluster was then labeled as one of the ground cover classes as defined by the CDF. (For a complete discussion of the CDF data set, see Benson and Beck, 1979.)

1.3.2 The Digital Terrain Data Set

The terrain data set used in this project was produced by the Defense Mapping Agency Topographic Center, and was made available in tape format from the National Cartographic Information Center (NCIC). Digital terrain tapes (DTTs) have been produced for the entire United States, and were digitized off the USGS 1:250,000-scale topographic series maps. The data are in 1° x 2° quadrangle format, and consist of elevation values that have been digitized and interpolated to a 200-foot contour interval. Each pixel represents an area of approximately 60-meters-by-60 meters. The terrain data for the Grapevine area were extracted from the Ukiah East DTT.

1.4 The Grapevine Coordinated Resource Plan Area

The Grapevine Coordinated Resource Plan area is located twenty miles west of Colusa. It encompasses 43,000 acres of parallel ridges trending north-south (Figure 1). The upland areas are composed of tilted sedimentary material; elevations in the study area range from 350' at the town of Sites, to approximately 2400' at Lodoga Peak. Soils are sedimentary in origin, and are generally thin and erosive. Vegetation consists of pure stands of chamise *(Adenostoma fasciculatum)*, manzanita *(Arctostaphylos sp.)*, ceanothus *(Ceanothus sp.)*, buckeye *(Aesculus californicus)*, mountain mohogany *(Cercocarpus betuloides)*, and yerba santa *(Eriodictyon californicum)*, with digger pine *(Pinus sabiniana)* dispersed throughout the steep slopes, and blue oak *(Quercus Douglasii)*, valley oak *(Q. lobata)*, and live oak *(Q. Wislizenii)* in the woodland areas.

The Grapevine Coordinated Resource Plan (1979) lists the vegetative components, and their respective proportion of the study area, as follows:

annual grass/blue oak	13.0%
chamise	26.5%
blue oak woodland	39.0%
annual grassland	17.0%
mixed chaparral	4.0%
riparian woodland	0.5%

The current management of the Grapevine Resource Plan area reflects the concern over the continuous coverage of chamise in the area. Included in the management techniques are sequential controlled burns in the chamise and mixed chaparral communities, as well as construction of fuel breaks on key ridges. Type-conversions are undertaken where soils can successfully support pasture instead of brush. Major efforts are currently focused on brush rejuvenation, which involves planned rotational burns, providing a mosaic of various age classes in the chamise community. This rejuvenation process reflects the idea that in many cases, the thin soils and steep slopes are unsuitable for type-conversion to pasture, thereby making chamise the most appropriate vegetative cover.

2.0 Processing Phase

In order for the analyst (and field personnel) to reference the spectral data and the terrain data to a ground coordinate system, registration of both data sets to a common geographic base was necessary. Figure 2 graphically represents the steps by which the data registration was achieved. The ground coordinate system chosen was the UTM grid system, which is based on a 1000-meter square grid. The UTM system was selected because (a) it is based on a square grid, and (b) it is found on most current USGS maps.*

Neither data set could be directly related to a common map base without some form of coordinate transformation or rotation step. The DTT data had been mapped originally to a UTM projection, while the CDF data set had been mapped to a Lambert Conic Conformal projection. Both types of projections have their attendant degrees of distortion. The task of determining the relationships between the two data sets and the UTM grid required the calculation of regression coefficients between (a) CDF point and UTM east, and CDF line and UTM north, and (b) DTT point and UTM east, and DTT line and UTM north. After the regression coefficients were determined, the two data sets could then be registered to the common UTM grid.

The processing phase during which the data sets were reformatted and overlaid is described below. Most of the details are specific to the RSRP interactive display system, but can be considered typical of other image processing systems. The details are included in order to clearly outline the processing steps which should be performed by remote sensing and data processing specialists before the data can be utilized.

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*Note: The UTM grid can be overlain on any map projection. It should not be confused with the UTM projection.

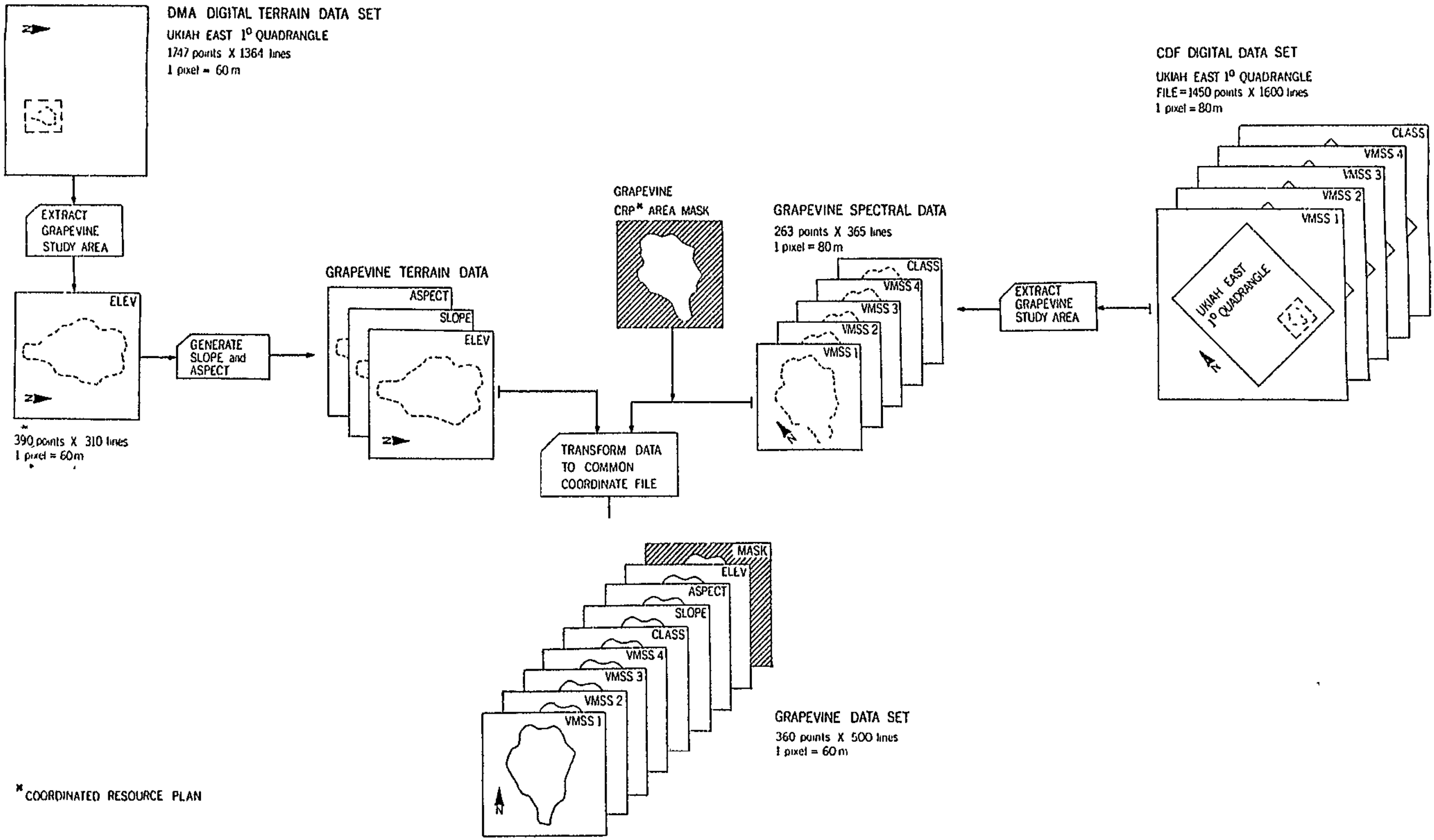

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Figure 2. Procedure used to develop the Grapevine data set. See text for details.

This is important, as a potential user of the CDF data set, or any data set, should understand the complexities involved when generating a data set and then transforming that data into useful resource management information.

2.1 Data Preparation

2.1.1 Reformat the CDF Data Set

The spectral data was received on computer compatible tape (CCT) and was converted to the RSRP compatible format. The original format consisted of five separate files, each 1450 points-by-1600 lines. The first four files corresponded to the four raw Landsat MSS bands, while the fifth file corresponded to the unsupervised classification of the first four bands. In order to simplify all subsequent processing and display procedures, all five files were reorganized into one file with five bands. The single file was also reduced in size (and therefore in its requirement for computer space) by extracting a rectangle 263 points-by-365 lines, within which the Grapevine area was located.

2.1.2 Generate the Digital Mask

The next step was to generate a mask, which, once applied to a band (or bands), would delete any data values outside the study area. Using the RSRP interactive display system, an outline of the study area was digitized, and a mask produced. The mask not only allowed the analyst to quickly grasp the configuration of the study area, but also reduced the amount of extraneous data that are both time-consuming and costly to process.

2.1.3 Reformat the Digital Terrain Data

The digital terrain data also had to be extracted from tape and converted to the RSRP compatible format. The DTT covered the entire 1° Ukiah East quadrangle, and consisted of approximately 1747 points-by-1364 lines of elevation data, with one pixel equivalent to approximately 60-meters^2. The coordinates of the 1° quadrangle were provided with the DTT data in one-hundredth-of-an-inch units (1 pixel = .01"). The study area (a rectangle drawn around the Grapevine area) was simply measured on the 1:250,000 base map with a scale, and the coordinate pairs of the four corners recorded as .01" increments from the origin. These coordinate pairs were then used to extract a portion from the DTT that encompasses the Grapevine area. The resulting rectangle consisted of 390 points-by-310 lines. The 16-bit elevation data were then reformatted to a single band file on the RSRP system for use and display purposes.

2.1.4 Generate Slope and Aspect Values

In order to enhance the topographic data set, the slope and aspect values of each DTT pixel were generated from the elevation data. These values were determined through use of a nearest neighbor algorithm whereby elevation values of a pixel's four adjoining neighbors are input, and then a "normal" vector is calculated representing a plane that corresponds best to the four elevation values (Figure 3). The coordinate values of the vector are then given their associated slope and aspect values, which are then assigned to the center pixel. Consequently, the terrain data set contained three bands of information (slope, aspect, and elevation), or three "features" for every 60-meter^2 pixel.

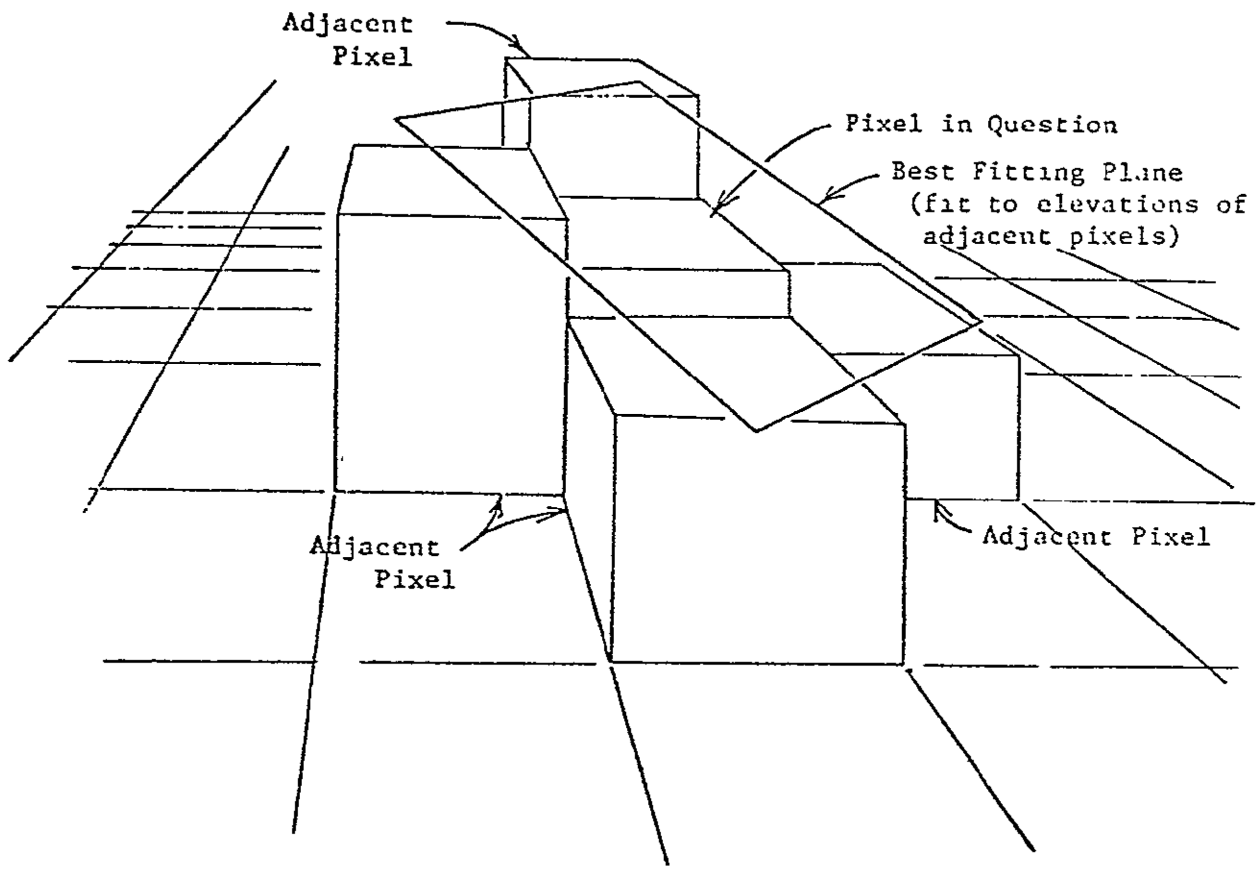

Figure 3. Graphic representation of the slope algorithm, which fits a plane to the four elevation values surrounding the pixel in question. From this algorithm, aspect can also be determined for the center pixel. For further discussion of digitally-derived terrain information, see Part II of this chapter.

2.2 Geographic Control

Geographic control was required in order to establish the relationship between the CDF data set coordinate system of "point and line", the terrain coordinate system of "point and line", and the ground coordinate system to UTM east and north for use in the field. With the establishment of these relationships, a discrete coordinate set, as read on the 1:250,000-scale topographic sheet, could be tied directly to the corresponding coordinate set in the CDF and DTT data, and vice versa.

The following steps were used to transform the spectral data and the DTT data to a common coordinate grid.

2.2.1 Spectral Data

Select control points. Control points were located on 7½-minute orthophoto map sheets for the Grapevine study area; in all, three orthophoto sheets were required to cover the entire area. These control points had to correspond to features that could be accurately located on both the orthophoto map sheet and the raw CDF image as displayed on the RSRP color monitor. This restriction limited the number of control points that could be located, because, in this region of considerable topographic dissection, the ridges could not be accurately represented due to the large pixel size of the CDF data (80-meters^2). In all, 52 control points were initially selected.

Calculate regression coefficients. Coordinate transformation can be achieved by either (a) rotation of the data to a UTM grid, or (b) linear transformation based on regression coefficients. The RSRP uses the latter for coordinate transformation. Four regression models were tested with the set of 52 points using a linear least-squares curve fitting program described by Daniel (1977). The four models are listed in Table 1(a). A series of iterations were performed on the data points in order to screen out those points whose residuals (i.e., the difference between the observed and the predicted values for the same point) were deemed excessive. If the residuals were excessive (i.e., greater than two pixels), the point was rechecked on the color monitor and on the orthophoto map sheet in order to determine if a simple measurement error was the cause for the difference. This screening process went through several iterations until the analyst was confident that all measurement errors had been corrected, and that any residuals present were due to the geometric properties of the Lambert Conic Conformal projection to which the CDF data set was mapped.

Based on their respective residuals and root mean square (RMS) errors, Equation 4 was chosen as the optimum model for predicting both CDF point-UTM east and CDF line-UTM north. The actual regression fits for CDF point and line are given in Table 2.

2.2.2 Terrain Data

Select control points. Establishment of horizontal control of the DTT data had to be conducted differently than the procedure for the spectral data outlined above. Although the DTT data were initially digitized off a 1:250,000-scale USGS topographic quadrangle, the projection upon which the map was based contains inherent distortion. In order to measure that distortion, the four coordinate pairs representing the corner points of the 1° quadrangle were used

Table 1a. The four regression models that were tested for the prediction of ground coordinates from CDF data set coordinates, and of CDF data set coordinates from ground coordinates.

Eq. 1. $$\text{CDF coordinate} = a + b_1[\text{UTM}_{east}] + b_2[\text{UTM}_{north}]$$

$$\text{UTM coordinate} = a + b_1[\text{CDF}_{point}] + b_2[\text{CDF}_{line}]$$

Eq. 2. $$\text{CDF coordinate} = a + b_1[\text{UTM}_{east}] + b_2[\text{UTM}_{north}] + b_3[\text{UTM}_{east}][\text{UTM}_{north}]$$

$$\text{UTM coordinate} = a + b_1[\text{CDF}_{point}] + b_2[\text{CDF}_{line}] + b_3[\text{CDF}_{point}][\text{CDF}_{line}]$$

Eq. 3. $$\text{CDF coordinate} = a + b_1[\text{UTM}_{east}] + b_2[\text{UTM}_{north}] + b_3[\text{UTM}_{east}]^2 + b_4[\text{UTM}_{north}]^2$$

$$\text{UTM coordinate} = a + b_1[\text{CDF}_{point}] + b_2[\text{CDF}_{line}] + b_3[\text{CDF}_{point}]^2 + b_4[\text{CDF}_{line}]^2$$

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Eq. 4. $$\text{CDF coordinate} = a + b_1[\text{UTM}_{east}] + b_2[\text{UTM}_{north}] + b_3[\text{UTM}_{east}]^2 + b_4[\text{UTM}_{north}]^2 + b_5[\text{UTM}_{east}][\text{UTM}_{north}]$$

$$\text{UTM coordinate} = a + b_1[\text{CDF}_{point}] + b_2[\text{CDF}_{line}] + b_3[\text{CDF}_{point}]^2 + b_4[\text{CDF}_{line}]^2 + b_5[\text{CDF}_{point}][\text{CDF}_{line}]$$

Table 1b. The regression models that were used for the prediction of ground coordinates from DTT data set coordinates, and of UTM data set coordinates from ground coordinates.

Eq. 1. $$\text{DTT coordinate} = a + b_1[\text{UTM}_{east}] + b_2[\text{UTM}_{north}] + b_3[\text{UTM}_{east}][\text{UTM}_{north}]$$

$$\text{UTM coordinate} = a + b_1[\text{DTT}_{point}] + b_2[\text{DTT}_{line}] + b_3[\text{DTT}_{point}][\text{DTT}_{line}]$$

Table 2. Regression fits for CDF point and line using UTM east and north as independent variables.

REGRESSION FIT FOR CDF POINT USING UTM EAST AND NORTH AS INDEPENDENT VARIABLES

Prediction equation: $CDF_{point} = 5462.0 \text{ meters} - .132363[UTM_{east}] + .0182667[UTM_{north}] + 1.929E7[UTM_{east}]^2 - 1.51523E6[UTM_{north}]^2 - 5.74374E7[UTM_{north}][UTM_{east}]$

Analysis of Variance

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F-Value
Regression	2.272E5	5	4.544E4	1.654E5
Residual (error)	1.044E1	38	2.747E-1	
TOTAL	2.272E5	N-1=43		

Range of residuals: -.751 points -to- +1.013 points

Root mean square error: .5242 points

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REGRESSION FIT FOR CDF LINE USING UTM EAST AND NORTH AS INDEPENDENT VARIABLES

Prediction equation: $CDF_{line} = 1327.32 \text{ meters} - 4.93507E\text{-}2[UTM_{east}] + 9.43599E\text{-}2[UTM_{north}] + 4.4746E\text{-}7[UTM_{east}]^2 + 8.67168E\text{-}7[UTM_{north}]^2 + 5.57759E7[UTM_{north}][UTM_{east}]$

Analysis of Variance

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F-Value
Regression	6.180E4	5	1.236E4	6.884E4
Residual (error)	6.823	38	1.795E-1	
TOTAL	6.180E4	N-1=43		

Range of residuals: -.969 points -to- +.750 points

Root mean square error: .4237 lines

in lieu of visually-located internal control points. These four coordinate pairs were supplied with the DTT, and were the most accurate points upon which to establish a set of regression coefficients between map bases.

Calculate regression coefficients. The linear least-square regression algorithm was performed on the DTT data, using the four coordinate pairs. The number of regression models that could be tested was limited, as there were only four control points. The equations used to predict DTT point-UTM east and DTT line-UTM north are listed in Table 1(b). Table 3 lists the actual regression fits for DTT point and line.

Because only four observations were used to calculate the three regression coefficients, the resulting prediction equation provided an exact fit between observed and predicted values. Therefore, in order to provide a check on the validity of the prediction equation, the expected center coordinates of the 1° quadrangle, based on analytic geometry, were calculated in terms of DTT units and UTM meters. The expected UTM east and north coordinates of the center point were subsequently input into the prediction equations (Table 3). The predicted DTT point and line coordinates were then compared with the DTT point and line coordinates as calculated using analytic geometry. As can be seen in Table 4, the differences between the predicted and the calculated DTT points and lines were within a fraction of the 63-meter pixel size of the DTT data. Based on the results of this check, the regression equations listed in Table 3 would provide good registration between the DTT data and the UTM geographic base.

Table 3. Regression fits for DTT point and line, using UTM east and north as independent variables.

REGRESSION FIT FOR DTT POINT USING UTM EAST AND NORTH AS INDEPENDENT VARIABLES

Prediction equation: $DTT_{point} = -68201.5 + 4.972E\text{-}4[UTM_{north}] + 1.580E\text{-}1[UTM_{east}] - 9.377E\text{-}11[UTM_{north}][UTM_{east}$

REGRESSION FIT FOR DTT LINE USING UTM EAST AND NORTH AS INDEPENDENT VARIABLES

Prediction equation: $DTT_{line} = -7815.29 + 1.573E\text{-}2[UTM_{north}] - 4.003E\text{-}6[UTM_{east}] + 8.005E\text{-}12[UTM_{north}][UTM_{east}]$

Table 4. Comparison between the use of regression coefficients versus the use of analytic geometry for estimating the center points of the UTM and DTT 1° quadrangles. The predicted coordinate pairs (px and py, derived from regression coefficients) and the expected coordinate pairs (ex and ey, derived form analytic geometry) for each respective data quadrangle differ by less than one pixel (63 meters).

PREDICTED

$$UTM_{coordinate} = a + b_1[DTT_{point}] + b_2[DTT_{line}] + b_3[DTT_{point}][DTT_{line}]$$

$$DTT_{coordinate} = a + b_1[UTM_{east}] + b_2[UTM_{north}] + b_3[UTM_{east}][UTM_{north}]$$

EXPECTED

$$\frac{Y_c - Y_{northwest}}{Y_{southeast} - Y_{northwest}} = \frac{X_c - X_{northwest}}{X_{southeast} - X_{northwest}}$$

$$\frac{Y_c - Y_{southwest}}{Y_{northeast} - Y_{southwest}} = \frac{X_c - X_{southwest}}{X_{northeast} - Y_{southwest}}$$

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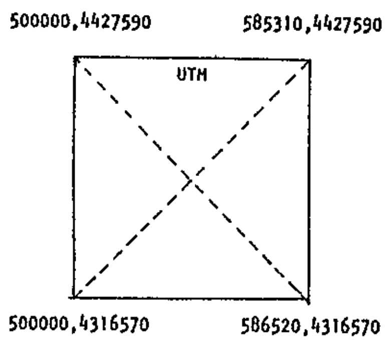
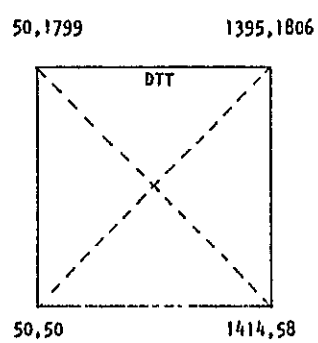


UTM_{px} = 4.96828E5 + 6.34312E1[727.39] + 1.02281E-4[934.38] + -2.04562E-6[727.39][934.38]

UTM_{py} = 4.31341E6 + -3 73686E-1[727 39] + 6.34751E1[934.38] + 2.39903E-5[727.39][934.38]

UTM_{px} = 542955.5 UTM_{ex} = 542965.93 Difference = 10 43 meters

UTM_{py} = 4372470 0 UTM_{ey} = 4372464.35 Difference = 5 65 meters



DTT_{px} = -7.81529E3 + 1.57306E-2[542955.5] + -4.00273E-6[4372470 0] + 8.00546E-12[542955 5][4372470 0]

DTT_{py} = -6.82015E4 + 4 97234E-4[542955.5] + 1.58008E-2[4372470 0] + -9.37712E-11[542955 5][4372470.0]

DTT_{px} = 727.229 DTT_{ex} = 934.382 Difference = 161 (10 22 meters)

DTT_{py} = 727.390 DTT_{ey} = 934.384 Difference = .002 (14 meters)

2.2.3 Determine Common Pixel Size

Before the transformation coefficients could be applied to the spectral and terrain data, selection of a common pixel size to which the respective data sets could be registered was necessary. If an 80-meter^2 pixel size were chosen, the resolution of the CDF data set would be unchanged, while the resolution of the DTT data set would become more degraded due to data compression during the resampling process. If a 60-meter^2 pixel size were chosen, however, the resolution of the DTT data set would be unchanged, while the resolution of the CDF data set would become more generalized due to data repetition during the resampling process. Therefore, the 60-meter^2 pixel size was selected, because the repetition of spectral data was preferred to the degradation of the already gross DTT data.

2.2.4 Transform Data Sets to a Single File

Using the regression coefficients established above, additional regression transformations were performed on the spectral and the terrain data. These regressions created new bands of data by resampling the original data sets using the first set of coefficients. The transformed bands were then written to a new file, thus becoming the new data set. This new file consisted of nine bands of terrain and spectral data, each 360 points-by-520 lines. Once the transformations were completed, all the data had both a common origin and pixel size. An analyst could then examine the topographic and spectral values for any pixel within the study area (see Figure 2).

2.3 Reference Grid

As a final step in the preparation of the Grapevine Coordinated Resource Plan data set, a 2000-meter^2 grid was superimposed on the raw and classified data bands. Figure 4 shows the grid's approximate location with respect to the Grapevine study area. This grid was positioned such that it corresponded to the actual UTM grid for the area, as determined from the orthophoto map sheets. The reasons for applying this grid were threefold: (1) to provide a common ground reference system for field crews; (2) for graphic display purposes; and (3) as a sampling frame for use during the labeling phase, as described below.

3.0 Labeling Phase

The labeling phase of the project involved the relabeling of the CDF classified data so as to reflect vegetation classes that would be more useful for land management decisions in the Grapevine area. The original CDF cluster labels, and the frequency of their occurrence, are listed in Table 5. Personnel from the RSRP met with SCS personnel from Colusa County in order to define a classification scheme that would help aid in brush control in the study area. The meeting resolved that refinement of the broad brush classes, as well as the hardwood classes, was desirable and necessary. The fuel management classes are listed in Table 6.

The steps required to relabel the CDF clusters are outlined in the following paragraphs, and are graphically represented in Figure 5.

3.1 Generate Ancillary Spectral Data

As an interpretation aid, three types of ancillary spectral values were calculated using the CDF data. The three consisted of the (1) mean

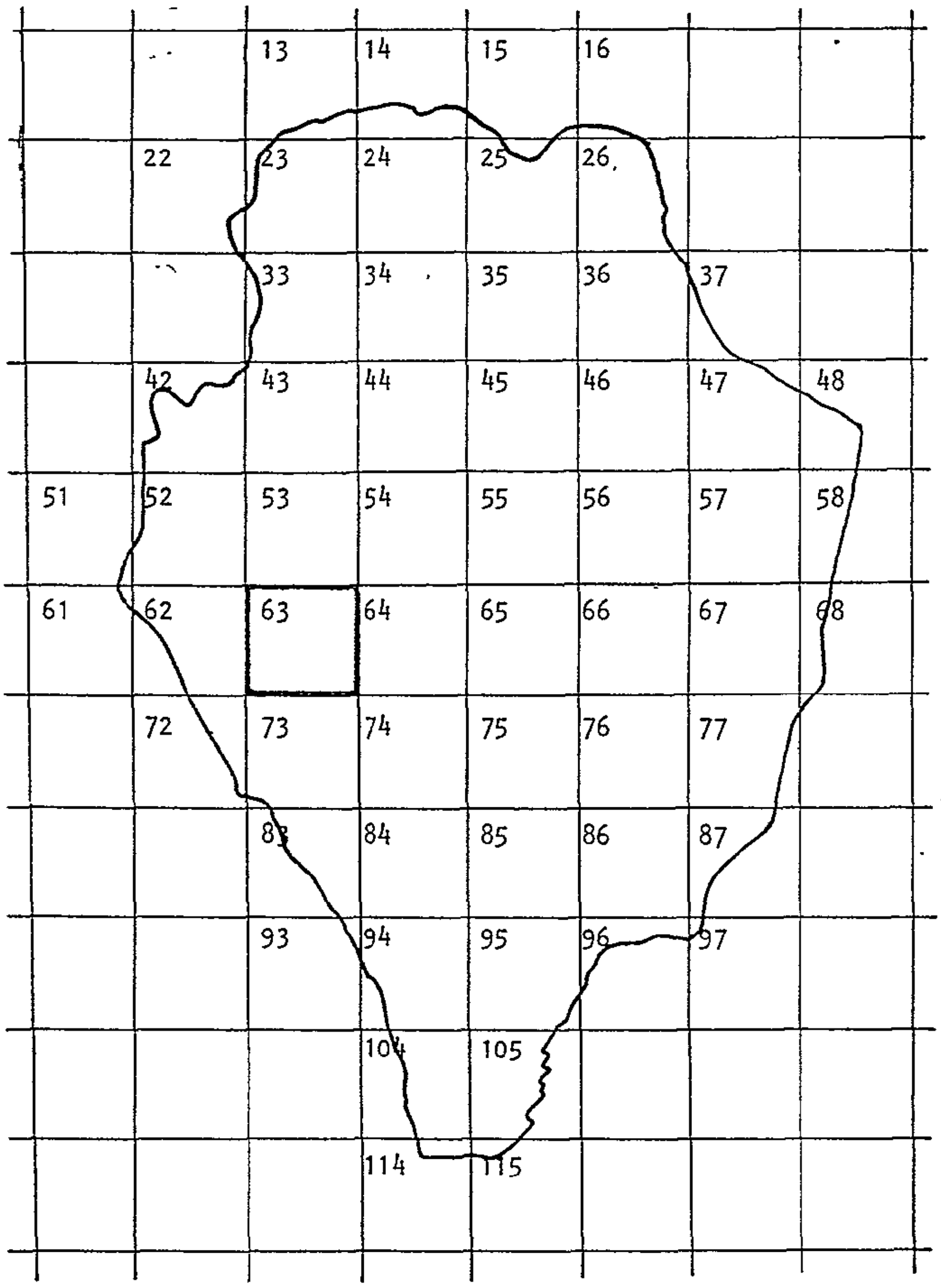


Figure 4. Location of the 2000-meter^2 UTM grid in relation to the Grapevine study area; numbers within each block refer to the block's row and column ID number. The distribution of spectral clusters in Block 63 are in Figure 6.

Table 5. CDF data set cluster counts for the Grapevine study area.

GRAPEVINE COORDINATED RESOURCE PLAN AREA

UKIAH EAST QUADRANGLE

CLUSTER NUMBER	SAMPLE COUNT	CDF LABEL
58	0	water
59	369	brush
60	5622	hard woodland
61	2610	brush
62	1648	brush
63	0	hardwood conifer
64	0	hardwood conifer
65	3177	hard woodland
66	32	brush
67	0	hardwood conifer
68	4276	hard woodland
69	0	hardwood conifer
70	0	hardwood
71	2698	hard woodland
72	0	conifer woodland
73	175	brush
74	2907	hard woodland
75	0	hardwood
76	2978	hard woodland
77	0	hard woodland
78	3879	grass
79	0	hardwood
80	17	grass
81	0	agriculture
82	1451	grass
83	2512	grass
84	2847	grass
85	0	agriculture
86	587	grass
87	813	grass
88	2848	grass
89	45	grass
90	132	barren
91	1444	barren
92	61	barren

*Refer to Part I, Table 2, for a description of the CDF labels.

Table 6. Fuel management classes for the Grapevine study area.

GRAPEVINE COORDINATED RESOURCE PLAN AREA

FUEL MANAGEMENT CLASSES

<u>VEGETATION</u>

Brush
- chamise - pure *(Adenostoma fasciculatum)*
- chamise/oak *(A. fasciculatum, Quercus sp.)*
- chaparral *(A. fasciculatum, Arctostaphylos sp., Aesculus californicus, Ceanothus sp., Cercocarpus betuloides, Eriodictyon californicum)*
- chaparral/hardwood mix

Hardwood
- hardwood - pure *(Quercus sp., Acer sp., Lithocarpus densiflora)*
- hardwood/brush
- hardwood/grass

Softwood
- conifer - pure *(Pinus sabiniana)*
- conifer/brush

Grassland
- grassland - pure *(Avena sp., Bromus sp., Hordeum sp., Festuca sp.)*
- grassland/hardwood
- grassland/riparian

Other
- barren
- water
- agriculture
- urban

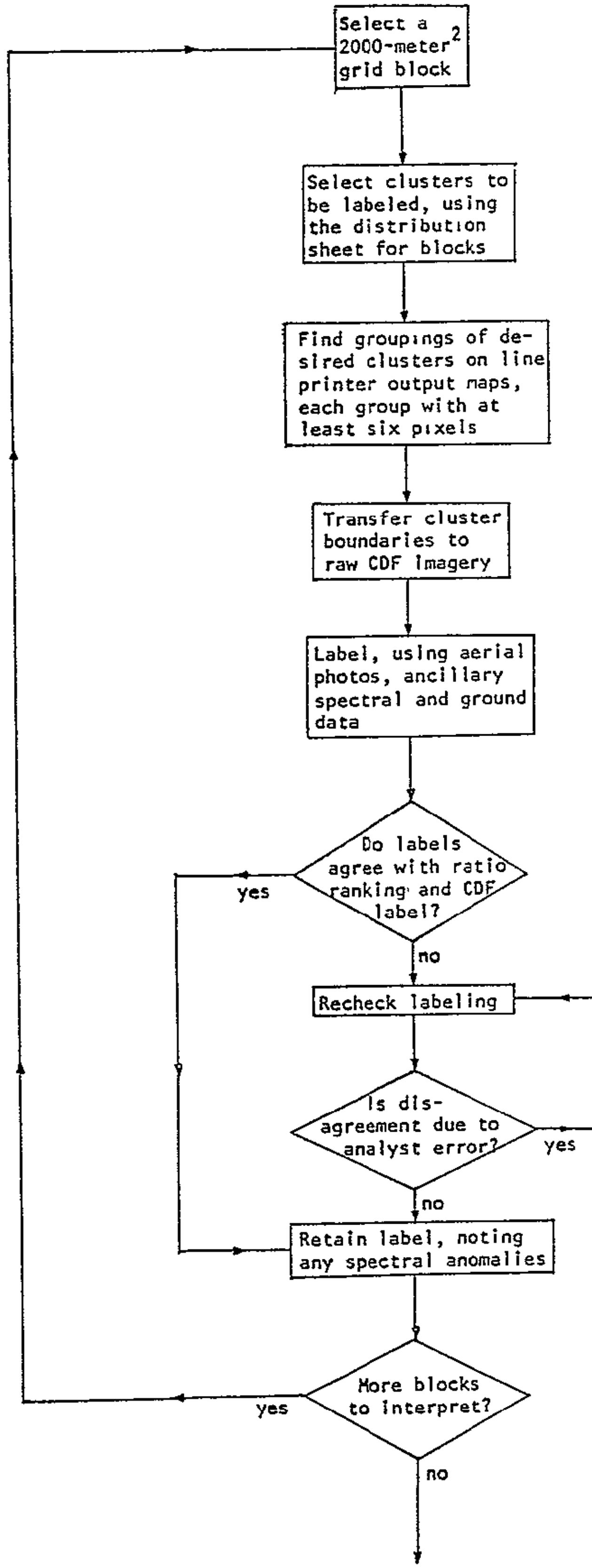


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Figure 5. Stepwise procedure used to relabel the CDF clusters.

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Band 4/mean Band 2 ratio; (2) mean Band 1/mean Band 2 ratio; and (3) Euclidean brightness (EB). Based on a cluster's relative ranking to other clusters in one or more of these data types, plus the original CDF label, the image analyst was able to set her expectations as to the probable fuel management label that could be assigned to that cluster. The mean brightness values from which these ancillary data were calculated are given in Table 7; the ranked clusters and ancillary data are given in Table 8.

The ratio of the mean of Band 4 (far reflectance infrared) to the mean of Band 2 (red) is an indicator of general vegetation condition. The ratio contains most of the spectral information regarding vegetation development while tending to normalize the influence of such confounding factors as solar radiation and topography (Nalepka, et. al., 1977). This ratio is also valuable for establishing the "soil line". Generally speaking, 4/2 ratios that are greater than 1.09 (the "soil line") indicate the presence of vegetation, while ratios below 1.09 indicate bare soil, water, snow, and other non-vegetated surfaces.

The ratio of the mean of Band 1 (green) to the mean of Band 2 (red) is an indicator of visual "yellow-greenness". This ratio is useful for labeling the annual grass classes which tend to have higher amounts of accumulated dried "yellow" vegetation along with green vegetation during and subsequent to senescence. This means that the 1/2 ratio tends to be lower for senescent grass classes than for other natural vegetation classes (Hay and Thomas, 1978).

The Euclidean brightness (EB) value is the sum of the Euclidean distances between the band means, and is calculated as follows:

Table 7. Mean brightness values for the CDF clusters.

CDF DATA SET: NORTH CENTRAL INTERIOR ECOZONE

CLUSTER NUMBER	SYMBOL	BAND MEAN 1	2	3	4
58	1	23.38	12.66	6.93	2.54
59	2	19.37	12.89	13.50	10.82
60	3	21.39	16.60	21.30	19.68
61	4	19.88	14.58	18.07	16.02
62	5	22.62	18.96	17.40	13.61
63	6	17.04	10.03	17.82	17.49
64	7	17.97	11.04	21.61	22.38
65	8	23.87	21.68	21.45	18.15
66	9	20.92	15.58	24.34	24.33
67	A	18.93	11.93	27.88	30.54
68	B	23.31	19.62	24.18	22.37
69	C	19.30	13.03	25.64	26.99
70	D	21.24	15.70	29.42	31.39
71	E	26.46	24.95	24.90	21.45
72	F	19.57	13.04	30.89	34.44
73	G	23.86	19.99	29.62	30.03
74	H	24.53	21.40	26.80	25.08
75	I	21.04	14.95	34.41	38.68
76	J	26.59	24.58	28.51	26.30
77	K	22.67	17.81	31.95	34.44
78	L	28.57	27.72	29.10	25.86
79	M	20.74	14.05	38.35	44.31
80	N	25.84	22.61	34.97	36.60
81	O	26.14	21.62	40.25	43.37
82	P	27.85	26.67	31.49	30.14
83	Q	30.08	29.95	32.34	29.85
84	R	30.95	30.97	30.54	25.96
85	S	23.89	16.52	46.19	53.83
86	T	28.68	27.16	34.31	33.82
87	U	31.75	32.14	35.71	33.51
88	V	32.87	33.72	33.30	28.76
89	W	30.71	29.84	39.39	38.72
90	X	36.25	30.09	40.80	36.12
91	Y	34.85	36.57	36.60	31.76
92	Z	41.70	47.91	46.98	41.04

Table 8. Ancillary spectral data for the Grapevine study area.

NORTH CENTRAL INTERIOR ECOZONE

	4/2 RATIO			1/2 RATIO			EUCLIDEAN BRIGHTNESS $(1^2+2^2+3^2+4^2)^{\frac{1}{2}}$		
RANK	MAP SYMBOL	CDF LABEL	VALUE	MAP SYMBOL	CDF LABEL	VALUE	MAP SYMBOL	CDF LABEL	VALUE
1	S	agriculture	3.258	1	water	1.847	Z	barren	89.026
2	M	hardwood	3.154	6	hardwood conifer	1.699	S	agriculture	76.647
3	F	conifer woodland	2.641	7	hardwood conifer	1.619	X	barren	76.232
4	I	hardwood	2.587	A	hardwood conifer	1.570	Y	barren	70.001
5	A	hardwood conifer	2.560	2	brush	1.503	W	grass	69 888
6	C	hardwood conifer	2.071	F	conifer woodland	1.501	O	grass	68.204
7	7	hardwood conifer	2.027	C	hardwood conifer	1.481	U	grass	66.627
8	O	agriculture	2.006	M	hardwood	1.476	V	grass	64 448
9	D	hardwood	1.999	S	agriculture	1.446	M	hardwood	63.731
10	K	hard-woodland	1.934	I	hardwood	1.407	T	grass	62.299
11	6	hardwood conifer	1.744	4	brush	1.364	N	grass	61.167
12	N	grass	1.619	D	hardwood	1.353	Q	grass	61.145
13	9	brush	1.562	9	brush	1.343	R	grass	59.360
14	G	brush	1.502	3	hard-woodland	1.289	P	grass	58.015
15	W	grass	1.298	K	hard-woodland	1.273	I	hardwood	57.848
16	T	grass	1.245	O	grass	1.209	L	grass	55.679
17	3	hard-woodland	1.186	G	brush	1.194	K	hard-woodland	55.118
18	H	hard-woodland	1.172	5	brush	1.193	J	hard-woodland	53.063
19	P	grass	1.147	B	hard-woodland	1.188	G	brush	52.422
20	B	hard-woodland	1.140	H	hard-woodland	1.146	F	conifer woodland	51.897
21	4	brush	1.099	N	grass	1.143	D	hardwood	50.483
22	J	hard-woodland	1.070	8	hard-woodland	1.101	H	hard-woodland	49.060
23	U	grass	1.043	J	hard-woodland	1.082	E	hard-woodland	49.018
24	Q	grass	.997	E	hard-woodland	1.061	A	hardwood conifer	46.937
25	L	grass	.933	P	grass	1.060	B	hard-woodland	44.860
26	X	barren	.924	T	grass	1.056	C	hardwood conifer	43.911
27	Y	barren	.868	L	grass	1.031	9	brush	43.183
28	E	hard-woodland	.860	W	grass	1.029	8	hard-woodland	42.771
29	Z	barren	.857	Q	grass	1.004	3	hard-woodland	39.675
30	V	grass	.853	R	grass	.999	7	hardwood conifer	37.538
31	2	brush	.839	U	grass	.988	5	brush	36.866
32	R	grass	.838	V	grass	.975	4	brush	34.510
33	8	hard-woodland	.837	Y	barren	.953	6	hardwood conifer	31.850
34	5	brush	.178	X	barren	.927	2	brush	28.994
35	1	water	.201	Z	barren	.870	1	water	27.593

$$EB = [\ (\text{mean Band } 1)^2 + (\text{mean Band } 2)^2 + (\text{mean Band } 3)^2 + (\text{mean Band } 4)^2\ ]^{\frac{1}{2}}$$

This value is a measure of the cluster's albedo, and is useful for making distinctions between brush subclasses (i.e., manzanita and chamise).

It is significant that the critical analysis of the ancillary data values that have been calculated for each spectral cluster is not as important as the relative rankings of the clusters within each ancillary data set. The actual values associated with vegetation types will vary among geographic regions of California. (See Benson and Beck, 1979, for an example of how an image analyst might use these ancillary data.)

3.2 Label Clusters by Block

In order to facilitate the interpretation of clusters, line printer maps showing the distribution of the spectral clusters were produced for each 2000-meter^2 grid block. An example of this type of output is shown in Figure 6. These cluster maps were used by the image analyst to visually determine the location of clusters on the raw CDF data, and subsequently on the color infrared U-2 imagery. Line printer maps were considered superior to color-coded photographic products because (1) they could be reproduced inexpensively, and (2) the alpha-numeric characters were found to be unambiguous identifiers for each of the 35 potential clusters in each 2000-meter^2 block.

The following three values were calculated for each cluster in order to aid in interpretation: (1) the pixel count present in each 2000-meter^2 block; (2) the percent of the block that the cluster represented; and (3) the percent of the cluster sample total that the cluster represented in the 2000-meter^2 block.

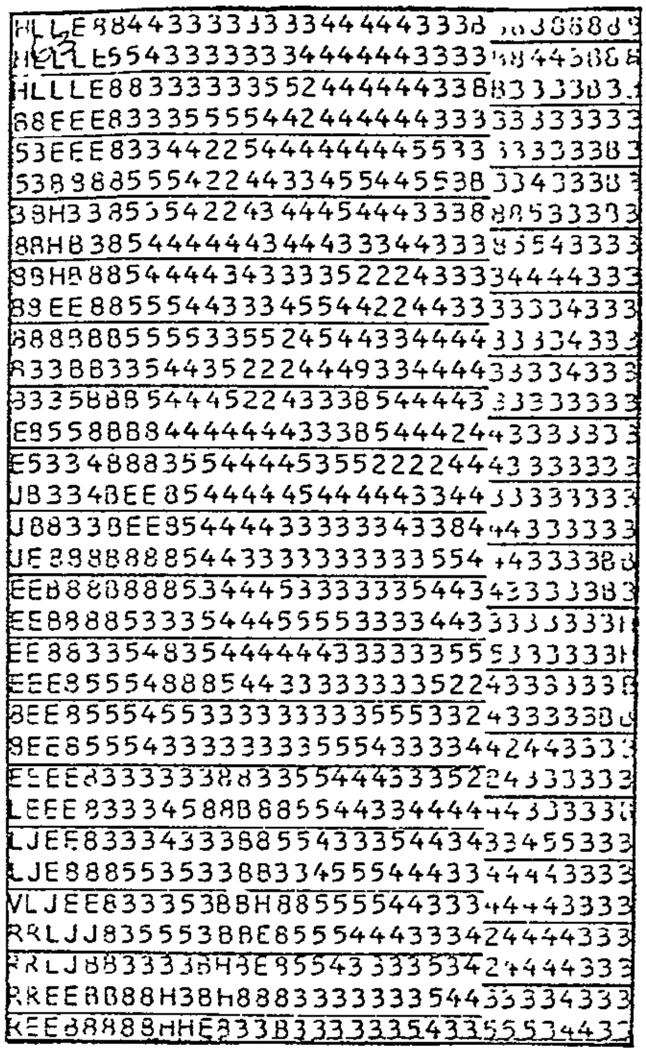


Figure 6. Line printer map showing the distribution of spectral clusters in Block 63. This area, as imaged on raw CDF data, orthophoto map sheets, and U-2 aerial photography, is shown in Figure 7a, b, and c respectively.

Select spectral sample block.

In addition, the pertinent U-2 photography, orthophoto map sheets, and ancillary data were assembled. For ease in locating clusters on the raw data, the 2000-meter^2 grid was overlain on both the U-2 photography and the orthophoto sheets. The CDF spectral image for Block 63, and associated ancillary image products, are shown in Figure 7.

Select clusters to be labeled.

By referring to the line printer maps and their associated spectral counts, the analyst determined which classes were best represented within the selected block. To facilitate the choice, a master sheet was compiled for each cluster on which was listed the blocks in which the largest population of each cluster could be found (Table 9). If the selected block contained a relatively large proportion of a certain cluster, the analyst made sure that she labeled that cluster in the block.

Locate groupings of desired clusters on line printer maps.

Large groupings of spectral clusters were outlined on the line printer output. Each cluster group consisted of at least six pixels. Considering the large number of clusters that were normally represented in a block, the line printer output was superior to color-coded photographic products in that it was easier to differentiate groupings of symbols than to locate groupings of subtle colors.

Transfer cluster group boundaries to raw CDF imagery.

The analyst transferred the cluster outlines to either a photo of the raw CDF image or to the interactive color display monitor. The an-

a b c

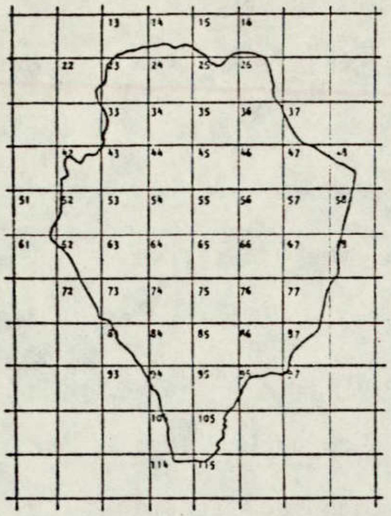
Figure 7. Graphic products used to relabel spectral clusters in Block 63.

(a) Raw CDF spectral image, 2000 meters-by-2000 meters.

(b) 2000-meter^2 UTM grid superimposed on the orthophoto coverage.

(c) 2000-meter^2 UTM grid superimposed on the U-2 coverage.

Table 9. Master chart showing cluster populations per 2000-meter^2 block in the Grapevine study area.



CDF DATA SET: NORTH CENTRAL INTERIOR ECOZONE

BLOCK NUMBER	CLUSTER NUMBER (SYMBOL) 59(2)	60(3)	61(4)	62(5)	65(8)	66(9)	68(B)	71(E)	73(G)	74(H)	76(J)
13		32	9	18	20		22	19		11	9
14		18			13		36	25		63	39
15								1		1	11
16							2				2
22									1	4	7
23	15	173	57	111	179		195	83		100	51
24	1	69	6	17	116		272	133		172	33
25	1	36	17	29	83		38	104	6	42	78
26					9		9	70		23	65
33	24	176	115	81	133		87	99		55	74
34		242	3	18	120		328	45		158	65
35	12	144	70	69	64	2	95	62		143	142
36					24		18	85	5	53	117
37								8		3	4
42	1	127	57	41	103		44	65		50	85
43	39	261	139	102	221		127	54		61	56
44	11	322	75	53	139		361	18		92	16
45	4	207	39	62	109	1	158	44	20	108	115
46		59	12	4	57		74	93	5	55	151
47					8			32		1	16
48											
51											
52	6	56	38	68	110		20	160		8	58
53	30	429	312	100	69		109	16	1	25	3
54	19	324	164	62	73	6	276	26	6	130	20
55	5	319	49	57	103		217	58	2	197	87
56		40	8	5	21	2	54	67	32	97	177
57					4		4	26	3	17	31
58											
61											
62		4	1	3	14		14	55		9	71
63	32	416	243	131	105	1	68	48		14	9
64	85	301	170	107	72	4	217	13		104	16
65	2	338	27	25	81	1	284	63	3	117	90
66	5	72	27	24	62	2	72	81	22	109	165
67							2	26		12	12
68											
72								4		1	8
73	34	169	235	97	127		35	85		17	39
74	15	362	328	57	44		83	18		23	6
75		246	39	15	84	7	290	56	6	182	84
76		116	34	47	121	4	128	120	8	117	121
77								26	3	1	34
83		47	21	52	190		28	79		40	82
84	19	182	184	48	75	1	117	61	5	119	101
85	3	95	43	28	42		80	58	5	98	140
86		33	5	14	147		66	165		26	98
87					1		3	21			11
93					1		1	10		5	12
94	4	142	68	51	75	1	100	56	19	94	87
95	2	22	5	25	45		55	72	8	64	91
96					6		5	24		3	13
97					1			2		1	4
104		16		7	50		44	82	12	32	61
105		27	10	20	52		35	67	3	47	53
114							1	3		1	2
115					1			6			

notated image was used as a visual link between the line printer output, the U-2 photography and the orthophoto map sheet.

Label clusters in block.

Each cluster group was located and identified on the U-2 imagery. The ancillary data, i.e., the orthophoto coverage, the 4/2 ratio, the 1/2 ratio, EB, and CDF labels, assisted in this labeling process by helping the analyst set her expectations as to the most probable label. In some cases, the analyst had access to ground data and personal knowledge of the sample block area, thus facilitating the identification of some of the spectral clusters.

Check labels against the ratio rankings and the original CDF labels.

If the fuel management labels were in general agreement with those of the CDF, the analyst then proceeded to another block. If there was disagreement (e.g., CDF label "hardwood" versus analyst label "chamise"), the labels within the block were rechecked for possible analyst error. The most common sources for analyst error were: (1) inaccurate transfer of cluster group boundaries to the raw CDF image and subsequently to the aerial photography, and (2) improper interpretation of ground conditions from the supporting aerial photography and ancillary data. If, after rechecking the label, the analyst did not change the fuel management label, the ambiguity between the labels was attributed to either (1) incorrect CDF labeling, (2) incompatibility between the definitions of the CDF and fuel management classes, or (3) spectral anomalies within the block.

3.3 Compare Cluster Labels for All Blocks

Each cluster was labeled in at least five blocks in order to ascertain the cluster's integrity throughout the study area; the cluster should represent the same type and condition of vegetation regardless of location within each of the spectral blocks. If a cluster was consistently identified as a certain type of vegetation, that label was assigned to the cluster, whether or not there was agreement with the original CDF label.

4.0 Evaluation of the Grapevine Data Set

Examination of the Grapevine data set has not been completed; even so, several weaknesses of the data set have become apparent. First, the DTT data were found to be severely lacking in topographic detail, with many of the ridges only appearing as truncated plateaus. As the ridge tops and north slopes contain important vegetative elements for fuel management, the DTT data's misrepresentation of the topography has proved to be unacceptable. An alternative to the DTT data seemed desirable; this alternative will be discussed below. Secondly, the spectral clusters displayed some marked inconsistencies. Although not wholly unexpected, the nature of these inconsistencies warrant further examination.

4.1 The Terrain Portion

As mentioned above, the DTT data were found to be far too general for application in the Grapevine study area. The area is topographically dissected, and the 200-foot contour interval proved to be inadequate for representing a meaningful net of elevation values from which slope and aspect values were derived. The aspect values were suspect, especially as many ridges were truncated, thereby creating "flat" aspects in lieu of junctions of north and south-facing slopes. This loss of terrain detail was unacceptable, as it was impossible to discriminate vegetation types by aspect.

The combination of topographic and spectral data is still considered to be a significant factor for fuel and resource management in the Grapevine study area. In Section 5.0 of this report, some recommendations for further work will be made in order to achieve a more cohesive data set.

4.2 The Spectral Portion

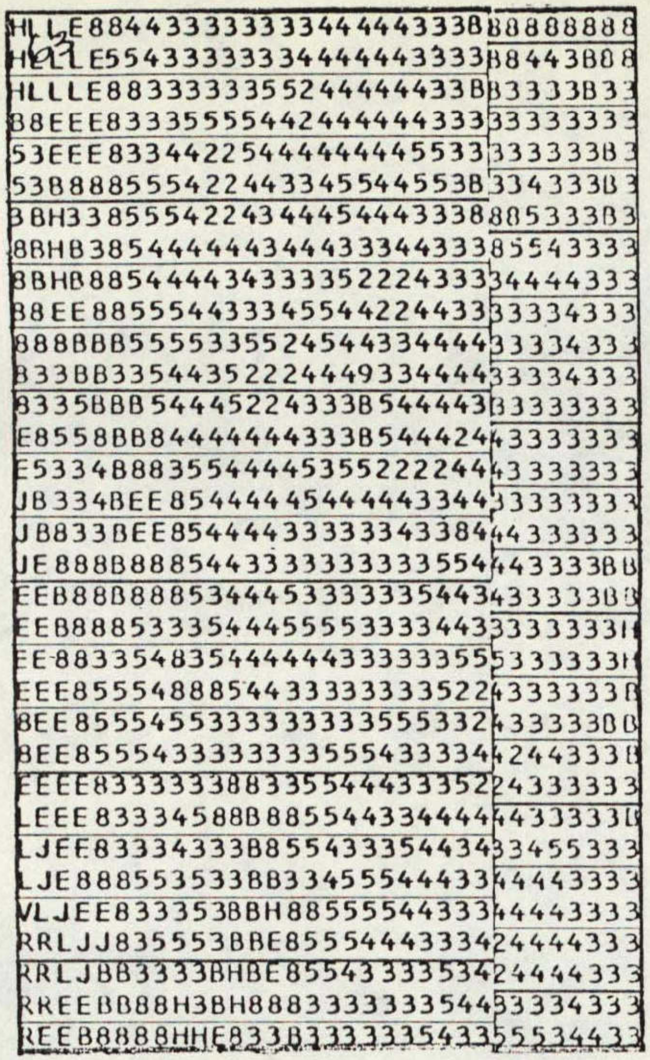
The spectral data posed some problems as well. Upon close inspection, a swathed small grains field located outside the western edge of the study area had a pink shadow along its northern boundary and a green one along its southern edge. This, coupled with similar evidence from other fields in the area, implied that there was misregistration of the MSS bands; this probably occurred when the Ukiah East quadrangle was mosaicked. Normally, one pixel misregistration is acceptable, and may be in this study area as well. However, the 80-meter^2 resolution of the spectral data, plus the slight displacement of bands, may have contributed to the often "fuzzy" appearance of the raw data, especially in the more highly dissected areas.

How the image appeared, however, is not as important as the integrity of the spectral data. The fifth band of the CDF data set consisted of an unsupervised classification of the first four bands. As the first four bands were slightly misregistered, it is probable that the data input to the classifier was misregistered enough to affect the ultimate clusterings. This misregistration was the most pronounced at the edge of vegetation types; unfortunately, the Grapevine area consists of many such edges. The only vegetative class to possibly escape this confounding effect might have been the pure stands of chamise, in which a pixel misregistration in any one band would not seem to be significant.

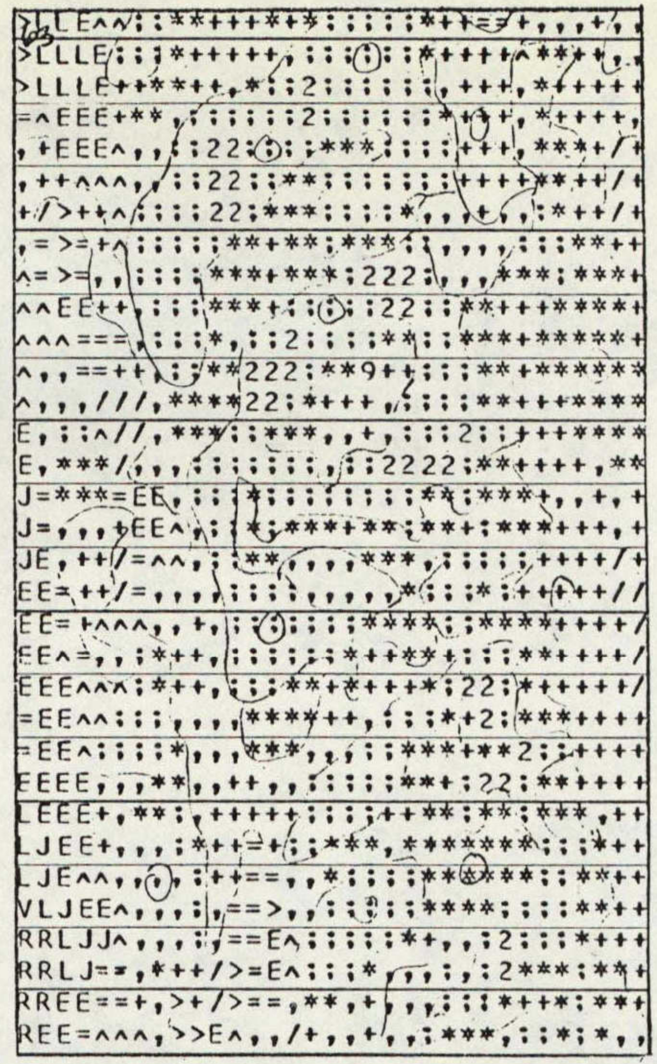
However, as the relabeling task proceeded, the analyst became more perplexed: seemingly pure stands of chamise, which should in all likelihood have been lumped together into fairly homogeneous clusters, had been broken out into five or six spectral classes. Conversely, west-facing slopes containing both chamise stands and patches of chaparral had not been broken into two or three classes, but had been generally thrown together into one class.

One might be tempted to speculate that the class fragmentation of the pure chamise stands could be attributed to the presence of different age classes or conditions within those stands, rather than to band misregistration. In order to help clarify this situation, further clustering was performed on the classified data, using the means from the original 35 classes to seed the statistics. This procedure yielded little significant change in the number of classes, or in their relative locations (Figure 8). (It was hoped that, by re-clustering, north and south-facing vegetation types could be discerned.) This procedure will be repeated on normalized data in order to determine if normalization of the four MSS bands will yield more informative cluster groupings.

The completion of the cluster labeling process must await further cluster processing. Until then, we have only an initial classification, with each cluster representing the vegetation class with which it was most often associated (Figure 9). Table 10 lists each class, with its

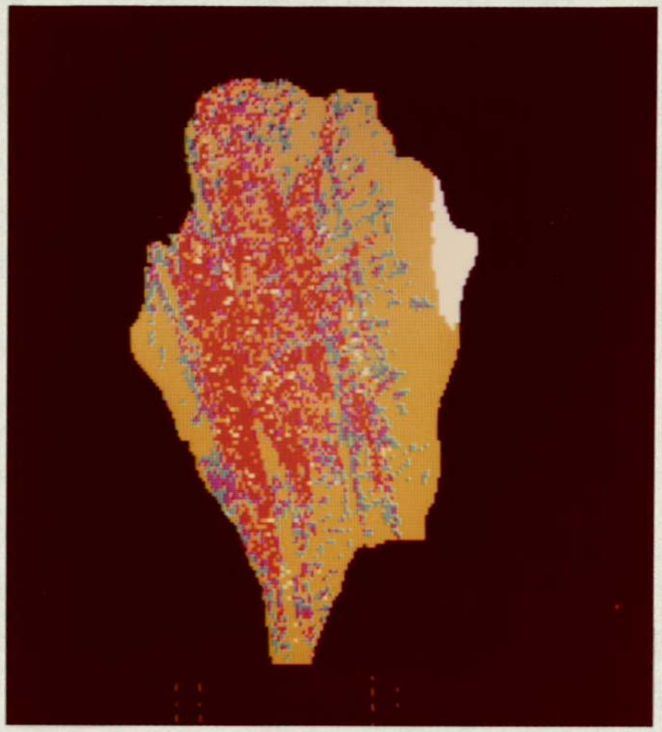


a) line printer map showing original classification of the CDF data set for Block 63.



b) line printer map showing results of re-clustering of the CDF classified data for Block 63.

Figure 8. Line printer maps for Block 63 showing the original CDF cluster distribution and the results of re-clustering of the CDF classified data.



brush -- light yellow
chamise -- red
chamise/brush -- orange
chamise/oak -- purple
oak woodland -- blue
grass, bare soil -- yellow

Figure 9. Preliminary distribution of fuel management classes in the Grapevine study area. The image was taken off the RSRP color monitor.

Table 10. A comparison of the CDF and fuel management labels that were assigned to the 35 clusters in the Grapevine study area.

CLUSTER NUMBER	SYMBOL	CDF LABEL	FUEL MANAGEMENT CLASS
58	1	water	*
59	2	brush	chaparral
60	3	hardwood woodland	chamise
61	4	brush	chamise
62	5	brush	chaparral/hardwood mix
63	6	hardwood conifer	*
64	7	hardwood conifer	*
65	8	hardwood woodland	chaparral/hardwood mix
66	9	brush	chaparral
67	A	hardwood conifer	*
68	B	hardwood woodland	chaparral/hardwood mix
69	C	hardwood conifer	*
70	D	hardwood	*
71	E	hardwood woodland	hardwood/grass
72	F	conifer woodland	*
73	G	brush	chaparral
74	H	hardwood woodland	chamise/oak
75	I	hardwood	*
76	J	hardwood woodland	hardwood/grass
77	K	hardwood woodland	*
78	L	grass	grassland
79	M	hardwood	*
80	N	grass	grassland
81	O	agriculture	*
82	P	grass	grassland
83	Q	grass	grassland
84	R	grass	grassland
85	S	agriculture	*
86	T	grass	grassland
87	U	grass	grassland
88	V	grass	grassland
89	W	grass	grassland
90	X	barren	barren
91	Y	barren	barren
92	Z	barren	barren

* indicates that cluster did not appear in the study area.

original CDF label and its fuel management label. These labels will be refined as processing is completed.

In addition, the difficulty experienced during the labeling phase could very well be due to the very dissected nature of the topography itself. Of course, any misregistration would confound this effect. As the vegetation on ridges of highly dissected relief tended to be more generalized by the clustering algorithm, it is almost certain that this dissection was missed due to the 80-meter^2 resolution of the MSS spectral data. Analysis of the raw data, in conjunction with the information derived from the DEM (see discussion below) data, may help resolve this problem. Then again, the CDF spectral data may prove to be inappropriate for highly dissected terrain.

5.0 Future Activities

As stated above, the combination of topographic and spectral data is still considered essential to the cohesiveness of the Grapevine data set. Because the inadequacies of the DTT data became apparent fairly early in the project, there was time to acquire DEM (Digital Terrain Model) data from the USGS. Complete discussion of this form of terrain data is presented in Part II of this chapter; however, it is perhaps appropriate to explain here why the DEM data will succeed where DTT data failed.

Basically, there are two reasons why the quality of the DEM data far exceeds that of the DTT data. First, the DEM data were digitized directly off aerial photography; conversely, the DTT data were digitized from 1:250,000-scale USGS topographic maps. The DTT data, therefore, could be no better than the original accuracy of the map from which the data were digitized, which for our purposes was far too poor. The DEM data were also tested out at a RMS error of 5 meters, and had good horizontal control.

The second advantage is the fact that the DEM data's resolution is 30-meters^2, as opposed to the DTT's 63-meter^2 resolution. It is therefore possible to represent finer topographic features with the DEM data. Also, the RMS error of 5 meters is sub-pixel in size, making these data very accurate.

The DEM data were recently received by the RSRP personnel, and work on reformatting and analysis has just begun. It is hoped that more sophisticated manipulations of the spectral data will be possible with the input of the DEM data.

As for the spectral classification, the final label assignments must await further work before the aforementioned inconsistencies can be resolved. This work is to include (1) processing of the DEM data; (2) using the DEM data to help label classes; (3) running the spectral classes through the clustering algorithm, this time normalizing the data bands; and (4) applying either DEM-derived slope and/or aspect values to the clustering process in an attempt to isolate any confounding influences topography may create. In addition, a solar illumination band will be generated from the DEM data and added to the Grapevine data set. By use of this band in the manipulation of the spectral data, certain features previously generalized by the original clustering may be enhanced.

Once the data manipulation phase is completed, a classified vegetation map will be produced on the RSRP film writer. This will enable SCS personnel in the field to locate areas of interest in the brush stands. Whether or not spectral variation can account for age classes within the brush community, the classification will allow field personnel to pinpoint anomalous areas which they can then inspect. The SCS personnel have already used some preliminary classification products to locate anomalous vegetation types in the field, and have found these products to be fairly promising. As inconsistencies are identified, the classification can then be further refined by relabeling the appropriate clusters.

The addition of slope information will also help in determining the type of fuel modification practice best suited to the terrain. The slope values will also be used to calculate the true acreage of vegetation types, not just the "paper acres" one usually computes from planimetric maps. These factors should significantly aid in the efficient allocation of personnel and equipment in the field.

Personnel from the RSRP and SCS have been keeping the Stonyford RCD committee current on the progress of this project. When the final geographic versions of the vegetation and terrain data are available, the committee will receive copies for review. The personnel from SCS have already supplied the RSRP personnel with some ground truth observations located in the study area. However, these observations were, in most cases, limited to vegetation alongside the study area's perimeter roads. When the final graphic products are ready, a statistical analysis will be undertaken by the RSRP personnel in order to ascertain the accuracy of the Grapevine data set.

6.0 Literature Cited

1. Benson, A.S., and L.H. Beck, 1979. An Investigation of the uses of digitally mosaicked Landsat data for mapping wildland fuel hazards in Mendocino County, California. Space Sciences Laboratory Series 21, Issue 1. University of California, Berkeley.

2. Daniel, C., and S. Wood, 1971. Fitting equations to data. Wiley Interscience. 342 pages.

3. Hay, C.M., and R.W. Thomas, 1978. Advanced AI aids and keys development. Space Sciences Laboratory Series 19, Issue 66. University of California, Berkeley.

4. Nalpeka, R.F., J.E. Colwell and D.P. Rice, 1977. Green measurement transforms. Appendix III in Forecasts of winter wheat yield and production using Landsat data. NASA CR ERIM 114800-38F. Environmental Research Institute of Michigan, Ann Arbor.

5. Newland, W., D. Peterson and S. Norman, 1980. Bulk processing techniques for very large areas: Landsat classification of California, in Proceedings of the International Symposia of machine processing of remotely sensed data. LARS, Purdue University, West Lafayette, Indiana. IEE Catalog #80 CH 1533-9 MPRSD. Pages 306-318.

6. Stonyford Resource Conservation District, 1979. Grapevine Coordinated Resource Plan.

APPENDIX A

MEMORANDUM OF UNDERSTANDING

UNITED STATES DEPARTMENT OF AGRICULTURE Soil Conservation Service Washington, D. C. 20250	UNITED STATES DEPARTMENT OF AGRICULTURE Forest Service Washington, D. C. 20250	UNITED STATES DEPARTMENT OF INTERIOR Bureau of Land Management Washington, D. C. 20240

I. PURPOSE

This Memorandum of Understanding, developed in consultation with the National Association of Conservation Districts, establishes policy and general guidelines for use by the Bureau of Land Management (BLM), Forest Service (FS), and Soil Conservation Service (SCS) for coordinating certain of their activities in resource planning and for working with Conservation Districts, State and Local agencies, private landowners who are conservation district cooperators, and other in developing and implementing sound resource management and conservation programs.

The May 19, 1971, agreement between BLM and SCS is hereby superseded.

II. POLICY

The Bureau of Land Management, Forest Service, and Soil Conservation Service will cooperate to the fullest degree possible in preparing and implementing resource management plans on operating units, allotments and other resource areas made up of intermingled or adjacent BLM and FS administered lands (hereinafter called public lands) and lands controlled by Conservation District (CD) cooperators (hereinafter called private lands).

The agencies cooperating on particular operating units or allotments will vary depending upon the landownership pattern within the planning area. The signatory agencies will seek to cooperate with all owners or managers of land and resources within each specific area -- including states, counties, or private owners. Other agencies and organizations will be involved as needed and appropriate.

III. AUTHORITY

BLM, FS, and SCS operate under separate legislative authorities and departmental policies including the following:

A. Soil Conservation Act, Public Law 46, 74th Congress, 1935, as amended, and Reorganization Plan No. IV, 1940, (16 U.S.C. 540a-f) and Comptroller General's Decision B-115665 (33C.G. 133), October 1, 1953.

B. The Taylor Grazing Act of June 28, 1934 (48 stat. 1269; 43 US Code 315 as amended).

C. National Environmental Policy Act of 1969, Public Law 91-190, 91st Congress, January 1, 1970.

D. Memorandum of Understanding between USDA and USDI dated April 20, 1942

E. Joint BLM-SCS Memorandum of April 10, 1964.

F. The Organic Act of June 4, 1897 (30 Stat. 35, as amended; 76 Stat. 1157; 16 U. S. C. 551)

G. The Multiple Use-Sustained Yield Act of June 12, 1960, (74 Stat. 215, 16 U. S. C. 528-531)

H. Title III, Bankhead-Jones Farm Tenant Act of July 22, 1937 (50 Stat. 525) as amended 76 Stat. 745), 7 U. S. C. 1010-1012.

I. Memorandum of Understanding between the Forest Service and Bureau of Land Management dated October 26, 1966.

J. Wild Free-Roaming Horses and Burros Act - P.L. 92-195 (85 Stat. 649, 16 U. S. C. 1331-1340)

K. All other applicable statutes and regulations not specifically referred to above relating to BLM, FS, and SCS programs.

IV. RESPONSIBILITY

A. The BLM and FS plan and conduct multiple-use resource management and conservation programs on lands under their jurisdiction. FS also has responsibilities to demonstrate and promote sound grasslands agriculture and conservation practices on the National Grasslands and areas of which they are a part.

B. The SCS provides technical and financial assistance to conservation district cooperators and participants in USDA cost-share programs for planning and applying authorized conservation programs on privately controlled lands.

C. The Conservation Districts, which are legal subdivisions of state government, develop annual and long-range programs, secure and coordinate assistance from appropriate agencies and organization, encourage and enter into cooperative agreements to assist individuals, groups, and units of government in conservation planning and application, provide means for determining local attitudes and objectives, and serve as catalysts to develop and maintain local interests in and support for conservation and development of resources.

V. OBJECTIVES

The objectives of coordinated resource planning are:

A. To promote cooperation between agencies and individuals to improve management and compatible use of the resources for which each is responsible.

B. To implement resource management plans to achieve compatible resource uses based on sound ecological relationships for logical management areas such as operating units, grazing allotments, and subwatersheds.

C. To optimize a sustained flow of food, fibre, and other goods, services and benefits from such lands while at the same time protecting and enhancing environmental qualities.

VI. GENERAL CONSIDERATIONS

A. Interagency reimbursement will not be made for planning and application assistance done under this memorandum.

B. BLM and FS will contact users of the public lands that are included in planning areas under their jurisdictions, and will retain responsibility for meeting all requirements of the laws and regulations pertaining to the use and management of these lands.

C. Cooperator contacts and followup assistance will normally be made by the agency having primary planning responsibility or will be mutually agreed upon before the onset of planning.

D. When any practices, structures, or projects are to be applied to or installed upon public lands under the jurisdiction of the BLM or FS, authorization must be obtained from the appropriate agency prior to initiation of the action.

E. The priorities and management objectives for BLM and FS administered lands will be determined through the responsible agency's planning system. However, special consideration normally will be given to resource areas presenting opportunities for coordinated resource planning.

F. Conservation districts will be encouraged to have memoranda of understanding with BLM, FS and/or other appropriate public land agencies at the local level.

G. When requested by the administering agency, SCS may provide technical assistance on public land intermingled or adjacent to private lands covered by a resource management plan when results benefit the private land.

H. Where State and private forests and related lands are involved the Forest Service will discharge its responsibilities through the appropriate State organization.

VII. STATE COORDINATION

A. STATE EXECUTIVE GROUP - The State Director (BLM), State Conservationist (SCS), and Regional Forester and/or Area Director (FS) will comprise this group. The chairman, State Conservation Commission, Committee, or Board, as appropriate, will be invited and encouraged to become a member. This group will develop and put into effect supplemental agreements, as needed, to meet the objectives of this memorandum, including procedure for specific programs to achieve agency coordination and cooperation throughout the State. They will meet annually to review progress, outline a course of action with appropriate followup, and otherwise facilitate coordination of agency procedures and programs. Representatives of the State Association of CD's and other appropriate State and Federal agencies such as State land, forestry, and wildlife agencies will be invited to participate in this meeting.

B. STATE TASK GROUP - This group will follow through with implementation of coordinated planning in the state. It shall be small in number but include representatives of major land and resource agencies including BLM, SCS, FS, and appropriate state agencies.

C. Conservation District Meetings - When invited by the CD, the BLM, SCS, and FS, as appropriate, will present reviews of proposed resourc activities of concern to the District. Other agencies involved in the coordinated approach will be encouraged to do the same. The CD's will be encouraged to give due consideration to such activities when developing long-range programs and assigning priorities and work schedules for inclusion in their annual work plan.

VIII. INITIATING, PLANNING AND SCHEDULING

A. Initiation - The State Executive Group will arrange to acquaint field personnel with this memorandum to assure mutual understanding and interpretation.

B. Planning - Active participation by all key participants, from inception to completion of the planning process, is essential. The planning team should include representatives from all landowners and resource administering agencies within the operating unit, allotment, or resource area. A team leader should be designated for each planning unit considering such items as landownership pattern, location of the area, time and manpower needs and resources involved. Where full-time agency participation is not warranted, suitable review of the arrangements should be made at the local level so interagency coordinated planning can proceed with reasonable assurance that the final plan will be acceptable to all.

C. SCHEDULING - Each agency and group has its own program of activities for which priorities are established. Coordinated resource planning should be made to dovetail with each agency's activity schedule. This requires a reasonable amount of give-and-take between agencies and with conservation districts in the selection and assignment of priority to requests for coordinated plans. The State Executive Group will jointly prepare guidelines useful at the county and local levels in determining priorities, assigning responsibilities, and scheduling needed assistance.

IX. MODIFICATION

This agreement shall remain in effect until modified by the parties in writing; and is renegotiable at the option of any one of the parties.

ENDORSEMENT

George R. Brady 1/21/75
President, National Association of Conservation Districts

APPROVALS

Curt Berklund JAN 15 1975
Director, Bureau of Land Management

Kenneth E. Grant
Administrator, Soil Conservation Service
JAN 10 1975

R. H. Kesler JAN 14 1975
for Chief, Forest Service

PART IV

WILDLAND FUEL HAZARD ASSESSMENT IN SHASTA COUNTY, CALIFORNIA

by

Andrew S. Benson

Table of Contents

1.0 Introduction

1.1 Background

On 31 October 1979, the first meeting of the Shasta County Fuel Break Planning Committee was held in Redding, California. The membership of this committee was composed of interested persons from County, State and federal agencies along with local advocacy groups and private citizens. A listing of the members of this committee is shown in Table 1. The objectives of this committee are, quite simply, to develop and implement aggressive brush land management in eastern Shasta County (Figure 1). The expected benefits of such a program would be to reduce fuel loading, increase water yield, increase livestock production, improve wildland habitat, increase forest productivity, reduce soil erosion, reduce air pollution, and improve esthetic values.* A letter from the County Farm Advisor to the Board of Supervisors completely describing these goals is given in Appendix 1 along with the minutes of the 31 October meeting. These items have been included here to indicate that (1) there is a strong desire of wildland management personnel to shift from custodial to active management of brushlands in Shasta County, and (2)

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*It is interesting to note that these objectives are almost identical to those identified by the Mendocino County Fuel Management Committee in 1976 (see Cosentino, et al 1976). Much of the interest in aggressive fuel management in Shasta County can be credited to our continuing successes in Mendocino County. These successes, in turn, can be credited largely to the continuing support, by Mendocino County's resource managers, of our remote sensing applications research in Mendocino County.

Table 1. Agencies participating in the Shasta County Vegetation Management Project

FEDERAL AGENCIES

- U.S. Forest Service--Shasta-Trinity National Forest
- U.S. Forest Service--Shasta Lake District
- Agricultural Stabilization and Conservation Service
- Soil Conservation Service

STATE OF CALIFORNIA

- Department of Forestry
- Department of Fish and Game
- University of California--Cooperative Extension, Davis Campus
- University of California--Remote Sensing Research Program, Berkeley Campus

SHASTA COUNTY

- Board of Supervisors
- Cattlemen's Association
- Farm Bureau
- Farm Advisor
- Air Pollution Control District

OTHER

- William F. Beaty and Associates
- Private ranch operators and land owners

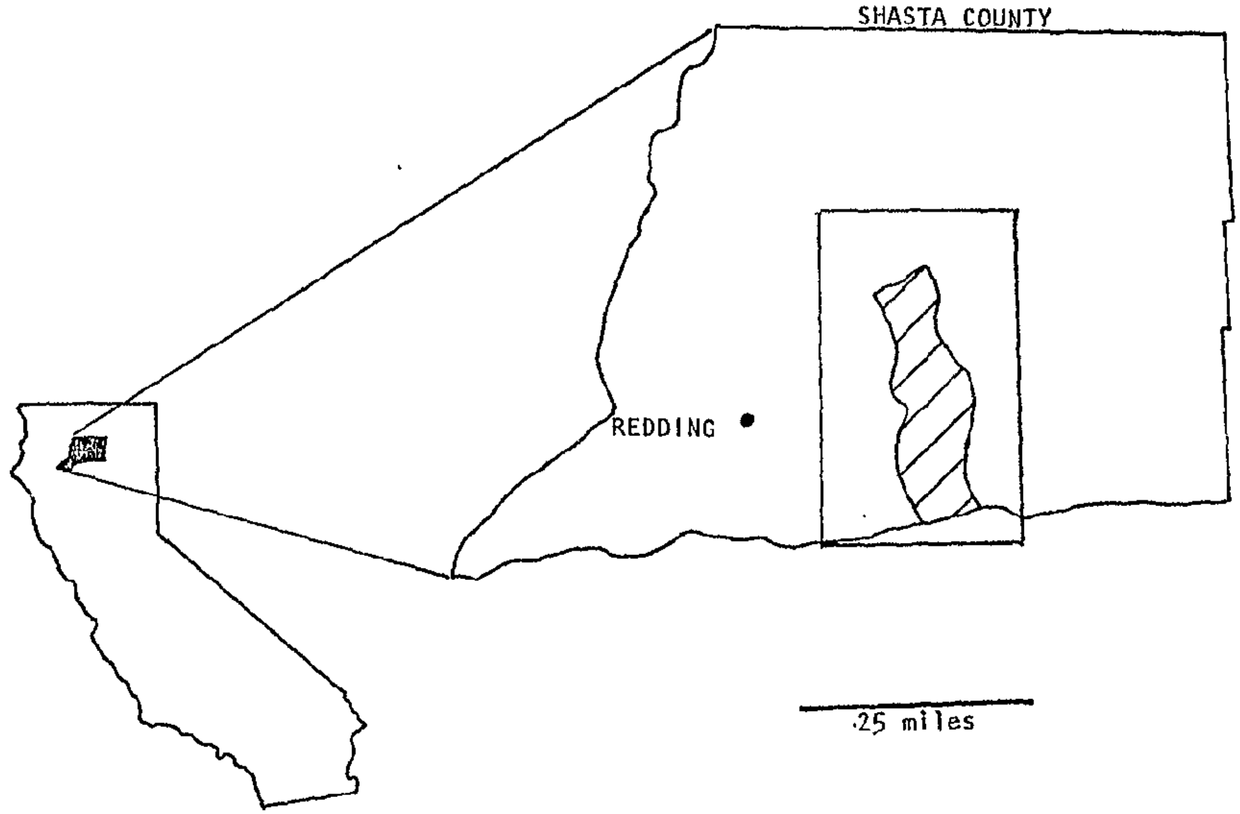

Figure 1. Location of Shasta County in northern California. Personnel from the Remote Sensing Research Program, University of California, Berkeley, have been providing support to the County Vegetation Management Committee which is initiating aggressive fuel management actions in the central third of the County. The rectangular area represents the initial 821,000 acre study area which was subsequently reduced in size to the 196,000 acre study area (cross hatched) through the manual analysis of raw and classified Landsat data.

state-of-the-art remote sensing may substantially assist in the acheiving of these goals.

1.2 Objectives

Initially, the primary objective of the involvement of our RSRP personnel with the Shasta County Vegetation Management Project (VMP) will bè to provide a wildland fuel map which can be integrated with other forms of auxiliary data (particularly data pertaining to property ownership). The resulting data set will be used to assist in the development and implementation of fuel management plans in Shasta County. The basic vegetation map will be derived from the statewide classified Landsat data set produced for the California Department of Forestry. (See Chapter 2, Part 1 for a complete description of this data set.)

2.0 Results to Date

During the first Shasta County VMP meeting, we assisted in defining a large study area (821,000 acres) for initial consideration (see Figure 1). The property ownership area is composed predominately of private land holdings, and there is no accurate, current, uniform vegetation map available. Personnel from the RSRP extracted this study area from the existing classified CDF data set. The resulting eight-class thematic map, representing the major ground cover, and the corresponding tabular data were given to members of the VMP for further analysis.

It should be noted that the data extraction process for the 821,000 acre study site only required eight hours of simple computer processing such as reformatting data, creating data files, and dumping tabular classified data. This rapid turn-around illustrates one of the real advantages of the CDF data set. By contrast, if a conventional unclassified

Landsat data were used for such a project, it would require at least 8 months to provide an equal product, and at a cost that might be prohibitively expensive to an unfunded organization such as the VMC.

Fuel management personnel from the VMP closely analyzed the vegetation patterns on the raw and classified CDF data set products, and, based on this analysis, reduced the size of the study area to 196,000 acres. This is a good example of the simplest, and perhaps the most effective, use of Landsat imagery. By allowing the land manager to look at his entire area of responsibility, this imagery permits him to identify areas of particular interest, based on vegetation and land use patterns, for further intensive study. Obviously, such a stratification process could be done using conventional aerial photos, but the cost of purchasing and mosaicking 500-600 aerial photos for an area this size can become prohibitive. The raw and classified images extracted from the CDF data set for this smaller area are shown in Figures 2a and b, and the associated tabular data are given in Table 2.

3.0 Work To Be Completed During 1980-81

Now that an intensive study area has been defined, fuel specialists from Shasta County and remote sensing specialists from the RSRP will refine the vegetation classes given in the thematic map shown in Figure 2b to make them more applicable for wildland fuel management. The relabeling process will include the following steps:

1. Define fuel management classes. Fuel management personnel from the Shasta County VMC will define those vegetation classes which reflect their specific management information needs.
2. Prepare auxiliary spectral data. Remote sensing specialists

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185

(a)

(b)

Fill = black; Water = blue; Conifer = green;
Brush = yellow; Barren = gray; Grass = lavender;
Woodland = white; Hardwood = red.

Figure 2. Raw (a) and classified (b) images of the 196,000 Shasta County Fuel Management Study Area. These two images, photographed off the RSRP color monitor, were extracted from the Redding East and Susanville West quadrangles of the statewide Landsat mosaic developed for the California Department of Forestry.

Table 2. Distribution of wildland fuel classes in the Shasta County Fuel Management Study Area based on the Landsat-derived CDF data set. Colors refer to the thematic map in Figure 2b.

CDF CLASS	NUMBER OF PIXELS	ESTIMATED* ACREAGE	PERCENT OF TOTAL AREA	NUMBER OF SPECTRAL MODELS
Conifer (green)				
conifer	6282	10302	5.25	13
conifer-hardwood	9300	15252	7.78	6
Subtotal Conifer	15582	25554	13.03	19
Hardwood (red)				
hardwood	10043	16471	8.40	12
hardwood-conifer	12920	21189	10.81	4
Subtotal Hardwood	22963	37660	19.21	16
Woodland (white)				
conifer woodland	3969	6509	3.32	4
hardwood-woodland	23644	38776	19.78	7
Subtotal Woodland	27613	45285	23.10	11
Brush (yellow)				
brush	31450	51578	26.31	25
open shrub	12386	20313	10.36	3
Subtotal Brush	43836	71891	36.67	28
Grass (lavender)	7167	11754	5.99	10
Barren (gray)				
barren	1997	3275	1.67	9
bare rock	127	208	.10	3
Subtotal Barren	2124	3483	1.77	12
Agriculture (black)	31	51	.03	1
Water (blue)	239	392	.20	5
TOTAL	119555	196070	100.00	102

*1 pixel ≅ 1.64 acres

from the RSRP will prepare spectral aids from the CDF classified data to supplement the existing cluster labels.

3. Label clusters. The spectral clusters which represent the ground conditions in the study area will be relabeled as specific fuel management classes. Personnel from the Shasta County VMC will go to Berkeley to perform this operation on the RSRP image display system.

4. Prepare and implement fuel management plans. Information derived from the thematic map and tabular data produced in (3) above will be integrated with property ownership maps and other auxiliary data. The resulting data set will be used to prepare fuel management plans on the basis of which fuel modifications actions will be carried out.

4.0 Literature Cited

Cosentino, Michael, Andrew S. Benson, Ida Hoos and James Sharpe, 1977. Fuel mapping in relation to the management of brushlands and timberlands in Mendocino County, California. Space Sciences Laboratory Series 18, Issue 52, University of California, Berkeley, California, 94720.

COOPERATIVE EXTENSION

UNIVERSITY OF CALIFORNIA

(Cascade Office Building)
2430 HOSPITAL LANE, ROOM 55
REDDING, CALIFORNIA 96001
TELEPHONE 246-5621

SHASTA COUNTY

October 15, 1979

COOPERATIVE FUEL BREAK PROJECT

Honorable Board:

Forestry, recreation, and agriculture are major segments of Shasta County's economy. They are based on natural resources such as soil, water, vegetation, and wildlife. The protection and enhancement of these resources should insure that these industries continue to be major contributors to our economy. Such protection and enhancement of the resources can be accomplished through the use of vegetation management to develop a large scale fuel break along the interface of range and timberlands.

Vegetation management in this case means the reduction of large amounts of living and dead hazardous fuels on our ranges and timberlands. It would include brush control on widespread areas, and could also include the reduction of other types of hazardous fuels in adjacent timberlands.

Over 40 years of research and demonstration by the University of California in Shasta County and other parts of California have shown brush control can protect and improve our resources:

* Fuel loading, fuel hazards, and fire hazards are reduced
* Yield of water from springs and streams is increased
* Livestock production is increased
* Wildlife habitat is improved
* Forests become more productive
* Soil erosion may be reduced
* Air pollution may be reduced and controlled
* Esthetic value can be improved

In order to obtain these multiple benefits for the county a number of people have been talking about trying to develop a large fuel break that can offer protection to our valuable forests, ranges, and rapidly developing rural residential areas from disastrous and costly wildfires; and at the same time produce the increases in water yield, livestock and wildlife production, timber growth, and soil stability. All along the hills on the west, north, and east sides of the valley are locations where such fuel breaks would be valuable, but it seems necessary to concentrate in one area at this time.

A special project is proposed for the foothill area east of Redding and running generally from the Pit River and Round Mountain south to Oak Run, Whitmore, Shingletown, and Battle Creek near Manton. This area has been

Appendix 1

selected because there are vast acreages of timber to the east, there has already been much progress made by ranchers in range improvement and fuel modification, and most of the range and adjacent timberlands are privately owned. Specific boundaries of the project area are not delineated presently, because complete vegetation and ownership patterns are not readily available.

It is assumed that the most rapid progress can be realized through the actions of private landowners based on incentives of one kind or another. Inquiries are presently being made to determine what, if any, incentives might be available to encourage landowners to reduce fuel hazards. Since participation in the project will be voluntary greater participation should be realized if some incentives are available.

Many individuals and organizations have expressed interest in developing this project and making it work. Included among those interested are the California Department of Forestry, Shasta County Cattlemen's Association, Shasta County Farm Bureau, timber managers, University of California Cooperative Extension and research staff, Agricultural Stabilization and Conservation Service of USDA, California Department of Fish and Game, and Shasta-Trinity National Forest. Representatives of these groups have scheduled a meeting Wednesday afternoon, October 31, at 1:30 p.m. in Room 39 of the Cascade Office Building to start more formal planning of the project. We all believe that such a project can be highly beneficial to many interests of Shasta County.

Our request to the Board of Supervisors is that you give consideration to the proposed project, that you endorse the project in principle if you agree that it will be beneficial to the County, and that you appoint one or more Board members to represent the Board and meet with the planning committee on October 31.

If I can supply you with any additional information I will be happy to do so.

Sincerely yours,

Walter H. Johnson

Walter H. Johnson
Farm Advisor

WHJ:dw

FUEL BREAK PLANNING COMMITTEE

October 31, 1979

The first meeting of the planning committee was held in the Shasta County Cascade Office Building with the following people in attendance: Royal Burnett, CDF, Shasta; Gilbert Belcher, CDF, Shasta, Ralph R. Ramsey, USFS, Redding; Carl P. Schuettke, USFS, Shasta Lake; Gary Harlow, CDF, Redding; Edward M. Crans, Wm. F. Beaty and Associates, Redding; Dave Smith, CDF&G, Redding; Lynne Wenck, USDA-ASCS; Glenn W. Aldridge, Shasta County Farm Bureau; Bob Stein, Shasta County Cattlemen's Association; Randy Reeves, SCS, Redding; Harry Rutherford, Shasta County Cattlemen's Association; John Caton, Shasta County Supervisor; Ted Adams, UC Cooperative Extension; Andrew S. Benson, Remote Sensing Research Program, UCB; and Walt Johnson, Farm Advisor.

Walt Johnson reviewed the background behind the proposed project, the developments that have taken place to date, and the purposes of the meeting.

Lynne Wenck explained various possible programs available through the Agricultural Stabilization and Conservation Service. There are regular ACP programs that would be available to participants in the proposed project. These programs relate to various vegetation management activities in agricultural and forest land; and they have a maximum cost sharing payment of $3500 per operator, although funding has been limited. Prescribed burning has not been an approved ASCS practice, but a special request for approval of prescribed burning is being submitted by the Shasta County ASCS Committee. ASCS also has a "Special Project" category in which they provide cost sharing assistance, and the funding for special projects is separate from funding for the regular ACP program. There is presently $40,000 in the special project fund, and it is unknown what will be in this fund next year. In special projects existing ACP practices can be used, and special practices could be developed if needed. Lynne pointed out that any application for special project funding should get in soon; and an application must identify the area, establish a boundary, state the problem, include ownership information and potential participation, and estimate the costs involved. There is also funding available for "pooling agreements," where three or more adjacent landowners join together to solve a common problem. These agreements involve more red tape, they must be approved by the State ASCS Committee, and the maximum cost sharing per farm is $10,000.

Dave Smith said that the Department of Fish and Game would certainly be in favor of such a project because of the value it might have in improving wildlife habitat. F&G has budget problems but they might be able to come up with a little financial assistance or equipment aid if their activities could be clearly shown to be in the public interest. The requirement of public access to private lands may or may not be a problem depending on the type of activity worked on. He felt they could certainly stimulate support from sportsmen.

Ed Crans pointed out that timber operators would certainly be interested in the protection that might be provided by reducing fuel hazards along the range land-timber land interface, and pointed out that there had been severe timber losses in recent years. He indicated that timber operators might not be undertaking a great deal of activity in fuel management projects.

Appendix 1 continued

Gil Belcher stated that the helitorch is a new development that can be very helpful in getting off-season burning done to reduce fuel supplies.

Royal Burnett pointed out that Gary Buzzini, ranger-in-charge, is definitely in favor of such a project. If there can be better advance planning of areas and cooperators to be involved in prescribed burning projects there would be a better chance for CDF to supply standby equipment, perhaps con crews, and the remote possibility of bulldozer standby if conditions are satisfactory. If the project proceeds along as everyone expects there should be effort made to seek an amendment to AB 1006 (Keene) to get the project area included as an area that would have exemption from state liability for suppression costs if permit conditions were complied with. CDF has no equipment available for prescribed burn preparations. To do the best job they need to get pressure off the peak burning period of July. He indicated that the project should be termed as "vegetation management."

Gary Harlow pointed out that the state, as of July 1, has a new forest improvement program involving cost sharing activities funded in the amount of $5,000,000 statewide, the funding coming from revenues of state forests. He indicated that some properties within the proposed project area might qualify under some of the state FIP programs. There is an individual in CDF in Sacramento working actively in projects relating to wood energy, he would be interested in working and helping with the special Shasta County project, and would need a definition of the project area and estimates of potential types and amounts of fuel available. One question is whether fuels are satisfactory and whether they can get to a boiler economically. Gary has color coded soil vegetation survey maps available that could be helpful in developing the project.

John Caton pointed out that the county air pollution permits are being issued through CDF for range improvement burns, and there is no requirement for burners to acquire these permits from the county office. He pointed out that the Shasta County Board of Supervisors has endorsed the project, and has appointed him to represent the Board in the planning of the project. He indicated that he could request endorsement of the project from other supervisor associations if this was deemed desirable. He could also look into the question of whether there are any legal tax incentives that might be available or developed for project cooperators. There should also be investigation into woodcutting and energy projects that might go along with the overall objectives. There is also the possibility that a computer printout of land ownership within the project area, along with maps, could be available through the assessor's office. Such a printout might also develop a mailing list so potential cooperators could be informed by mail as well as by other means. He felt that "Fuel Break" would be a desirable name for the project.

Ralph Ramsey said that the U.S. Forest Service would be interested in the project, and pointed out that their lands in the northern end of the project area are under CDF fire protection. USFS would have technical advice available, and might also have some equipment that could be helpful. One of

Appendix 1 continued

these pieces of equipment is the helitorch which they expect to test in the Big Bend area in the near future. The helitorch costs about $2000, but its use in tests to date have substantially reduced their burning costs. One test of 400 acres figured out at 59 cents per acre. A 55-gallon drum of the fuel used in the helitorch can go up to one mile in length and 10 feet in width. There are YCC and YACC crews, and it would have to be checked to see if these might be available for use in a special project.

Carl Schuettke indicated that the Shasta Lake District was getting involved in fuel management activities.

Andy Benson described the vegetation mapping programs that the UC Remote Sensing Unit has been involved with, these programs costing about 2-3 cents per acre. They have been able to define vegetation down to areas as small as 1.1 acre. It might also be possible to include property ownership on vegetation mapping. He showed a number of very fascinating things they had done in their research program. Andy indicated that there was enough going in this project and enough different aspects that it could be included in their research program and that they could provide vegetation mapping to this project free of charge. He indicated this might be completed sometime in January depending on how quickly the basic data could be obtained from NASA.

Bob Stein, Harry Rutherford, and Glenn Aldridge pointed out some of the activities cattlemen had been involved in, some of the accomplishments, some of the many problems, and the importance of such a project to the entire area. Everybody agreed that a good selling job would be required.

Randy Reeves said Soil Conservation Service felt the proposed project was very good and they would provide whatever assistance they could.

It seemed agreed by all to pursue possibilities of ASCS support, the availabili of ownership information in the courthouse, and the establishment of a general project area boundary running from Pit River to Battle Creek between 1000 and 3500 feet elevation, with the specific boundary to be defined after ownership and vegetation information is available.

It was also agreed that this committee must keep functioning and should meet again as soon as more information is available.

Walt Johnston

Appendix 1 concluded

CHAPTER 3

CENTRAL CALIFORNIA STUDIES

Co-Principal Investigator: John E. Estes

Co-Experimenter: Michael Cosentino

April, 1980

Geography Remote Sensing Unit
University of California
Santa Barbara, California 93106

Remote Sensing Interface with Decision Systems -Tod Streich

On October 8, 1979, the University of California at Santa Barbara, Geography Remote Sensing Unit, and the County of Santa Barbara entered into a cooperative project in order to study selected effects of a general plan amendment upon the County's rangeland economics. One task of this project encompassed evaluating a computerized environmental information system (EMIS) designed to allow County personnel to collect and manage a wide variety of data types including remotely sensed imagery. Part 1 of this annual report contains the University's evaluation of the environmental information system. Appendix A to Part 1 examines the great potential of using Landsat-derived information with EMIS.

The author gratefully acknowledges support from the National Aeronautics and Space Administration (NASA) [Office of University Affairs] (NSG 7220), which was used to prepare this report. Development of the VICAR-to-EMIS interface (see Part 1, Appendix A) was accomplished with funding from NASA/Ames (NAG 2-24). Finally, Santa Barbara County matched NASA funding for Department of Environmental Resources (DER) and Data Services personnel, without whom this report would not have been possible.

Anticipated funding for the next project phase (Part 1, section 4.0) will include NASA funds, and $20,000 which DER has requested in the FY 80-81 Santa Barbara County budget.

Watershed Runoff Study -Frederick Mertz

Part 2 of this annual report represents one year's funding from National Aeronautics and Space Administration (NASA [Office of University Affairs] Grant NSG 7220, with an approximate expenditure of $9,000. The research described in Part 2 was conducted in cooperation with the Kern County Water Agency (KCWA), which provided field surveys, watershed calibration computations, and personnel man hours. KCWA personnel will assist with future work including cluster labeling, field checking, error analysis, and model calibration for remote sensing derived inputs. KCWA has allocated funds for future processing provided acceptable results are obtained. In addition, KCWA personnel may utilize hardware and software at GRSU/UCSB for an information systems approach to runoff estimation. Analysis of the image processing techniques and runoff estimation procedures implemented in this research will follow as the Master's thesis of Frederick Mertz.

Chamise Mapping -Susan Atwater, Michael Cosentino

Funded by National Aeronautics and Space Administration (NASA) [Office of University Affairs (NSG 7220)], the chamise mapping effort is conducted with close cooperation of the US Forest Service personnel of the Los Padres National Forest (LPNF). All vegetation history and siting data come from records held by the US Forest Service. They established the parameters of this project by outlining their needs for chamise fuels information; i.e., age classes, slope classes, etc. Additional support of the project has come in the form of two undergraduate student internships. These interns are expanding the fire history map to include all of Santa Barbara County and researching the annual phenology of chamise chaparral and its response disruption by fire and man. The basis for this project comes from Master's thesis work soon to be completed by Susan Atwater on the use of Landsat data to monitor seasonal changes in chamise moisture content.

Range Management Study -Michael Cosentino, Michael Boyle

Funding for this project is provided on a matching funds basis between the National Aeronautics and Space Administration (NASA) [Office of University Affairs (NSG 7220, $ 5,000)] and the Santa Barbara County Department of Environmental Resources (DER, $15,000). Other cooperating agencies include University of California Cooperative Agricultural Extension Service, Santa Barbara County Executives Office, Santa Barbara County Planning Department, and Santa Barbara County Data Services. Resource management techniques such as those utilized in this project are being evaluated by DER for possible implementation in that agency's ongoing operations.

Perched Water Study -Elaine Ezra, Larry Tinney

Drainage related research during the past year, funded by National Aeronautics and Space Administration (NASA) Office of University Affairs (NSG 7220), was conducted in cooperation with the Kern County Water Agency (KCWA) and the Wheeler Ridge Water Storage District. These agencies provided depth-to-water table measurements and crop type information necessary for analysis of results from the Landsat remote sensing data used in this study. These agencies will continue to provide data to be used in further drainage assessment through Landsat remote sensing, which is the topic of Elaine Ezra's Master's thesis.

Contacts with the US Salinity Lab at Riverside, California, have opened a new avenue of support. This group has provided, and will continue to provide, data from ongoing research in Lost Hills, California, concerning variable salinity contents and the effects on crop condition. The Lab is very much interested in any methodology using remote sensing whereby salinity sampling strategies could be improved (e.g., stratified sampling based upon apparent crop condition), and has agreed to work with our group on this project.

Cotton Mapping from Landsat Imagery -Tara Torburn, Larry Tinney

During the past three years, the Geography Remote Sensing Unit,(GRSU), University of California, Santa Barbara, has been involved in research related to the mapping of San Joaquin Valley cotton fields in support of the joint state and federal pink bollworm control program. The initial development and preliminary portion of this effort was funded as part of this grant. Subsequent funding was provided through the NASA/Ames Consortium Agreement (NASA - Ames OR680-801) to incorporate historical Landsat data into the analyses and assess temporal reliability of the procedures. These demonstrations led to matching California Department of Food and Agriculture (CDFA) funds for a larger scale demonstration during the 1978 crop season (CDFA 7073). As part of our effort under this grant [(National Aeronautics and Space Administration (NASA) Office of University Affairs (NSG 7220)] we have continued to coordinate and document these additional research efforts. The goal has been to develop an operational procedure suitable for implementation by CDFA and/or United States Department of Agriculture (USDA) personnel. The combined results of these research projects, including an operational procedure, have been detailed in the Master's thesis of Tara Torburn.

CHAPTER 3

PART 1

Remote Sensing Interface
with Decision Systems

Author: Tod Streich

Table of Contents

1.0 INTRODUCTION

On October 8, 1979, the University of California, Geography Remote Sensing Unit and the County of Santa Barbara, entered into a cooperative project in order to study selected effects of a general plan amendment upon the County's rangeland economics. One task of this project encompassed evaluating a computerized environmental information system designed to allow the County to collect and manage a wide variety of county-wide data types including remotely sensed imagery. The following report contains the University's evaluation of the environmental information system.

The system chosen for evaluation is the Environmental Management Information System (EMIS) furnished by the Fresno County Planning Department. EMIS was partially developed by USAC funds in the early 1970's.[1] Fresno County obtained EMIS in 1974 and has extensively modified the system for responsiveness to the California State Laws of Planning and Zoning. EMIS is used as a production system in Fresno County and has been distributed to Orange and San Joaquin Counties where it is currently being used on a semi-production basis.

The evaluation of EMIS yielded two significant findings.

- EMIS is an extremely powerful tool for assisting local governmental personnel in planning and complying with land use legislation.
- The University does not have a thorough understanding of the operational structure of planning and permit processing as currently implemented in Santa Barbara County. Conversely,

County personnel do not fully grasp the operational infrastructure of geobased information systems. Due to this lack of a common understanding, the University, working in conjunction with County personnel, cannot recommend an immediate major implementation of EMIS. The University does recommend a more indepth evaluation of the system with a special focus on cost/benefit analysis.

1.2 STRUCTURE OF REPORT

The evaluation report is organized into four major sections:

- EMIS Description
- Evaluation
- Recommendations
- Alternatives

As much as possible, technical terminology is avoided in each of the sections; however, describing and evaluating a state-of-the-art high technology product cannot be undertaken without some reliance on standard geoprocessing concepts. Due to the unsatisfactory nature of communication between the County and the University on this evaluation, the Recommendations section of the report presents a framework for formalizing information interchange on a second phase EMIS evaluation. Finally, the Alternatives section provides a brief discussion of the options available to county permit processing management in the event of substantial revenue losses. Due to both the uncertainty regarding State funding during the next fiscal year and the University's incomplete understanding of Santa Barbara's operational permit processing structure, the discussion in the Alternatives section is necessarily tentative in nature.

2.0 EMIS DESCRIPTION

2.1 EMIS Implementation Objectives

The overall objectives of EMIS implementation include the following six components:

- Standardize the format of environmental data storage within the County.
- Improve the accuracy, consistency and availability of environmental data.
- Accelerate retrieval of environmental data for both permit processing and planning applications.
- Formulate linkages among data components colledted by various County Departments.
- Provide the County with the capability to process data captured by Federal and State level projects.
- Promote modeling of proposed development projects.

These are long term goals, and all six would only be attained through an intensive EMIS implementation effort.

2.2 EMIS Description

EMIS is an automated tool designed to assist planners in quickly analyzing spatially disposed information. EMIS consists of three major components: a computerized data base, computer programs and standardized procedures.

2.2.1 Computerized Data Base - The EMIS data base contains environmental information for a specific land area, for instance, Santa Barbara County. The data contained within includes descriptive taxonomies (attributes) as well as the geographic locations of each data type. The data base structure provides linkages between various data files. For instance, EMIS can link data from the Assessor's computerized data file with environmental data captured by D.E.R.* The EMIS data base would be resident on the County computer in the same fashion as existing Payroll files, Assessor data, etc.

Optimally, the EMIS data base should contain the entire spectrum of data used on a regular basis by County personnel. Examples of the various data types include the following categories.

Assessor Parcel Information - Non-confidential information for each parcel in the County is extracted from the Assessor's File and placed in the EMIS data base. This data has a wide variety of uses in both permit processing and advanced planning applications.

Topography - To a large extent, the County must approve or deny proposed development projects based on local topographical constraints. For instance, flood hazard, fire severity, erosion potential and viewshed impact are all derived from topography.

Soils - Soil Types impact erosion potential and land use suitability.

Geology - Earthquake fault zones and areas subject to liquefaction or landsliding affect site specific construction.

District Boundaries - The uses of school, utility (improvement,

*Department of Environmental Resources, Santa Barbara County water, sanitation, etc.) and administrative districts are fairly obvious for planning purposes.

Plan Boundaries - The spatial extent of General, Specific and Community Plan designations as well as proposed plan lines are used for consistency determinations.

Vegetation Cover - Fire hazard severity, biological habitats and land use suitability are partially derived from vegetative cover.

Zoning Designations - Zoning determines a number of site specific development limitations including allowable land uses, set back requirements and design guidelines.

Circulation Systems - The type and magnitude of a proposed development project are often determined by the service level of the transportation net.

Additionally, data such as historical/archaeological sites, rare and endangered species distributions, current land use, etc. can logically be placed in the EMIS data base.

2.2.2 Computer Programs - The EMIS programs provide a means of communication between personnel and the computer. Specific functions of the programs include:

- Verifying input data for the data base;
- selectively retrieving information from the data base. Information can be retrieved by either geographic location or by data type;
- organizing data from the data base into maps, tables, graphs and reports.

Additionally, the capabilities of the existing programs could be bolstered through a programming effort.

2.2.3 Standardized Procedures - EMIS is a complex system into which many individuals with varying backgrounds must interface. Well defined and documented operating procedures are mandatory for successful system operation. Because Fresno County has a different operational structure than Santa Barbara County, Santa Barbara could have to develop the standard procedures for EMIS operation.

2.2.4 EMIS Functioning - In either a permit processing application or an advanced planning study, EMIS performs exactly the same series of tasks that a human counterpart would perform. As an example, assume a minor subdivision application is being processed. In either system (existing manual or EMIS), the following types of tasks must be completed: determine zoning, verify land use, identify easements, evaluate historical/archaeological potential, etc. Except for the field work, EMIS completes the same amount of work as a planner. The major difference is that EMIS searches through an extremely compact, structured and organized data base, whereas the planner must access data from varying sources and mediums such as map sheets, textual materials and microfiche. Due to the organizational efficiency of data processing, EMIS can complete tasks in a few minutes that require hours of personnel time.

The actual application of EMIS consists of three separate components: building the data base, maintaining the data base and retrieving information from the data base for both permit processing and advanced planning purposes.

2.2.4.1 Building the Data Base - Before the EMIS programs can produce output, each piece of data desired for the data base must be converted to a format that the computer can process. For instance, printed maps must be "digitized" into the computer's memory. Tabular information must be either keypunched onto cards or keyed directly into the computer's memory. "Pre-digitized" data such as Landsat classifications, USGS digital quadrangle and LUDA data, and the California Department of Conservation's digital "important farmlands and soils" data must be put into EMIS format to complement/supplement the data base. The task of building the data base for Santa Barbara County will take years of personnel time. Note that the entire data base does not have to be complete for EMIS to be useful.

2.2.4.2 Data Base Maintenance - As parcels are subdivided and land uses change over time, the EMIS data base will have to be updated and maintained. No estimates are currently available for the magnitude of this effort.

2.2.4.3 Direct EMIS Applications - NOTE: the following examples assume either a complete or partially complete data base exists. EMIS provides two generic capabilities for retrieving information from the computerized data base -- by geographic area and/or by data type. For both types of searches, EMIS produces a report describing the information retrieved from the data base. For example, assume information is desired for a geographic area that is being proposed as a sanitary district. A series of geographic coordinates describing the outline of the proposed district would be input to EMIS. In turn, EMIS would produce a report covering the:

- number of parcels in the proposed district
- total area of the proposed district
- total area of various zoning classes in the proposed district by class
- total number of buildings (by type)
- mailing labels/post cards for each property owner in the area
- locations of existing sewer lines within the district
- existence and location of soil groups presenting special engineering problems
- flood prone areas
- existing tax structure.

Optionally, maps can be plotted to selectively display any or all of the information in the tabular report.

The above example illustrates a case where information about a distinct geographic area is required. A different approach is used when a planner wishes to know the location(s) of a specific data type, e.g. where are all Williamson Act Agricultural Preserves, or where are all the commercially zoned lands currently used for low cost residential housing? In this case, a report similar to the above would be produced, but the information would be aggregated by geographic area (supervisorial districts, traffic zones, census tracts, etc.).

2.2.5 EMIS Output Products - EMIS generates two output products: Printed reports and plotted maps. The content and format of the printed reports is established by the user department when EMIS is installed and remains in effect until the need for a new format is demonstrated, i.e., the format can only be altered through a programming effort. Figure 3-1 illustrates the report generated by Fresno County EMIS in response to a building permit application.

The maps produced by EMIS are used exclusively for checking the validity of data collected for the data base. Fresno County is currently testing recently developed additions to EMIS that provide for expanded graphic product generation.

3.0 EMIS EVALUATION

3.1 Technical Feasibility

There are no major technical problems associated with the installation of a batch oriented EMIS on the Santa Barbara County computer or the University Itel AS/6. The Santa Barbara County computer is effectively a mirror image of the Fresno County computer where EMIS now resides.

Two components of the EMIS system would require increased data processing budgets for the County: special input/output devices and increased storage capacity.

3.1.1 Special Input/Output Devices - Coordinate digitizing and graphic plotting are essential to EMIS functioning. Santa Barbara County currently does not have either a coordinate digitizer or a plotter and would be required to lease or purchase them. Additionally, if Santa Barbara County desires an interactive EMIS, additional programming will be required.

3.1.2 Increased Storage Capacity - All EMIS data files must reside on direct access devices. In the longterm, Santa Barbara County would

```
OUTPUT RESULTS BUILDING PERMIT PROCESS

PACS REQUEST   #00679      TERMINAL PLAN2

* * *     PACS ENTERED      * * *
NO LAND USE INVENTORY FOR
FOLLOWING PARCEL WAS FOUND
41607005

*********************************************************************

       **
     *    *           F R E S N O    C O U N T Y
   *        *
  *           *       P U B L I C    W O R K S
  **************
  * BUILDING * *
  **************          APPLICATION FOR
  *    * PERMIT *
  **************          BUILDING PERMIT

*********************************************************************

IDENTIFIER APN      41607005
SITUS ADDRESS    1341       W  MORRIS
WORD DESC
OWNER'S NAME AND ADDRESS
<< KRIKORIAN LEO S & MARGARET C/F DVA
 "<  1341 W MORRIS AVE
    FRESNO CALIF  93705
APPLICANTS NAME AND ADDRESS
     HAROL HART
     LOCUST CREEK

                              352
```

```
-----------------------------------------------------------------

                 GEOGRAPHICAL INFORMATION

-----------------------------------------------------------------

   SUMMARY OF PENDING ACTIONS ON SUBJECT AREA
        TYPE                        IDENTIFIER   DATE    STATUS
   -------------------------------  ----------   ------  -------
   REZONING                           NONE       ------   N/A
   CONDITIONAL USE PERMITS            NONE       ------   N/A
   VARIANCES                          NONE       ------   N/A
   DIRECTOR REVIEW & APPROVAL         NONE       ------   N/A
   BUILDING PERMITS                   NONE       ------   N/A

   SUBDIVISION REQUESTS               NONE       ------   N/A

IS SUBJECT AREA WITHIN 1/2 MILE OF CITY LIMITS -------- NO

IS SUBJECT AREA PERIPHERAL TO AN UNICORPORATED
   URBAN COMMUNITY WHICH IS NOT PERIPHERAL TO
   A CITY ? -------------------------------------------- NO

IS SUBJECT AREA PERIPHERAL TO AN UNINCORPORATED
   URBAN AREA WHICH IS PERIPHERAL TO A CITY ? --------- YES

IS SUBJECT AREA WITHIN AN ADOPTED URBAN
   UNIFICATION BOUNDARY ? ---------------------------- YES
        NAME   FRESNO

IS SUBJECT AREA WITHIN A SPHERE OF INFLUENCE ? -------- YES
        NAME   FRESNO

PARCEL DESCRIPTION(S)

PARCEL NO   WIDTH  DEPTH  TYPE SQ FEET    ACRES  FRONTAGE
---------   -----  -----  ---- -------    -----  --------

41607006  0001050000012042INTR00001338B        000010500
41607005  0001050000012042INTR00001309B        000010500
41607012  0001580000012400CUL00000193B7        00001239B
41607011  0001500000012042INTR00001901B        000015000
41607004  0001050000012042INTR00001358 9       000010500

        NOTE   THE ABOVE WIDTH, DEPTH AND FRONTAGE
               ARE IN HUNDREDTHS OF FEET

        NOTE   IF THE SUBJECT AREA'S WIDTH, DEPTH
               AND FRONTAGE ARE ZERO, THEY MUST BE
               DETERMINED BY THE DIRECTOR OF PLANNING

                              353
```

```
    LAST SALES DATE OF PROPERTY  081064
        ADJACENT OWNER(S) NAME

          CLEAVE JOHN H & JANE M
          KRIKORIAN LEO S & MARGARET C/F DVA
          CROSS RALPH J & MARGERY M
          JOHNSON HOWARD L & KATHLEEN

          ACKLEY EDWARD F

CURRENT ZONE(S)
                 I         NO.. ..
                --        --- ----

  .. IOR . ZONE(S)

     ZONE   DATE AMEND  PREVIOUS ZONES  ORD NO
     ----   ---- -----  --------------  ------

     R1AH  600608                       490

IS SUBJECT AREA IN AN AREA DESIGNATED URBAN BY
   A SPECIFIC, COMMUNITY OR GENERAL PLAN? ------------- YES
        PLAN NAME: COMMUNITY                   BULLARD

      DESIGNATED USE  LOW DENSITY RESIDENTIAL   0

DOES SUBJECT AREA CONTAIN AN EASEMENT(S)? ------------ YES
                    TYPE                  SIZE
                    ----                  ----

     PUE                                  0000

IS SUBJECT AREA UNDER LAND CONSERVATION CONTRACT? ----- NO

DOES SUBJECT AREA CONTAIN AN OUTLOT(S)? -------------- NO

DOES SUBJECT PARCEL HAVE ACCESS TO A TOWN ..
   MAINTAINED ROAD(S)? -------------------------

<<       UL. UL.
       TYPE MIN MAX    NAME
<<     ---- --- ---    ----

     LOC  40  40MORRIS AVE W

                              354
```

```
IS SUBJECT AREA AFFECTED BY A PLAN LINE? ------------- NO

IS COMMUNITY WATER AVAILABLE ON THIS OR ADAJACENT
   PARCEL(S) ------------------------------------------- YES
              DISTRICT NAME          SIZE-IN
              -------------          -------

           WATERWORKS DIST  NO 19     6

IS COMMUNITY SEWER AVAILABLE ON THES OR ADAJACENT
   PARCEL(S) ------------------------------------------- NO
           AGENT                  SIZE TYPE

           -----                  ---- ----

IS SUBJECT AREA IN A FLOOD PRONE AREA?  -------------- NO

IS SUBJECT AREA IN A FLOODWAY? ----------------------- NO

DOES A SPECIAL POLICY APPLY IN THE SUBJECT AREA? ------ YES
                 TYPE       NO
          ---------------- ---

          BLANKET VARIANCE 044

SOIL CHARACTERISTICS IN SUBJECT AREA
      CODE            DESCRIPTION
      ----            -----------

      SDA    SANDY LOAM SHALLOW 0-3% SLOPES

DOES SUBJECT AREA HAVE AN EXISTING PARCEL MAP
   ON FILE? -------------------------------------------- NO

              ANALYSIS OF ZONE/USE CONFORMANCE

****** ZONE DATA PLAN**   ********** USE DATA **********
                                       USE PERMITTED IN
       ZONE  DATE  ALLOW          USE   LCC     APPL    LCC
TYPE   CODE  ESTB  REZONE?  TYPE  CODE  APPLY?  ZONE    AREA

PREV   R1AH  60060          CUR   1111
CUR    R1AH

              CURRENT ZONE OF     R1AH
              URBAN
              LOW DENSITY RESIDENTIAL

                              355
```

Figure 3-1. Sample EMIS output from Fresno County. In this instance the output is in response to a building permit application.

ORIGINAL PAGE IS
OF POOR QUALITY

be required to increase the available direct access space in order to effectively support EMIS.

3.2 Cost Factors

Ascertaining the total cost of EMIS implementation for Santa Barbara County is beyond the scope of this project. A significant amount of costing information relating to the ongoing implementation of EMIS in Fresno and Orange Counties has been gathered. However, neither county has completed full system implementation; consequently it is not possible to derive accurate amortization costs. For instance, in the portions of Fresno County for which the EMIS data base is complete, permit processing costs are reduced approximately 70%. This reduction does not reflect the cost of building the data base though. An indepth cost analysis for EMIS implementation within Santa Barbara County is indicated.

3.3 Legislative Analysis

There is no legislation requiring the direct implementation of an environmental information system. However, the California Environmental Quality Act (CEQA) of 1970 and subsequent amendments mandate an environmental review process. AB884 (McCarthy, 1978) specifies a one year limit on the environmental review process. These two pieces of legislation, coupled with current limits on government spending effectively force lead agencies in rapidly expanding economic areas to examine automated assistance. As an example, AB2560 (Imbrecht, 1978) was enacted specifically to fund county level evaluations of the technology.

3.3.1 <u>California Environmental Quality Act</u> - EMIS can materially assist in the environmental review process by formalizing the location, consistency and accuracy of County environmental data.

3.3.2 AB884 (McCarthy, 1978) - EMIS accelerates the environmental review process thereby ensuring compliance with this legislation.

3.3.3 Subdivision Map Act - EMIS can provide ancillary support to the data gathering phase of subdivision permit processing.

3.3.4 General Plan Conformance - EMIS can determine the conformance of any proposed project with the relevant Plan (General Plan Element, Specific Plan, etc.) only to the extent that the Plan itself can be rendered machine readable. EMIS can probably provide only marginal assistance in this area.

3.3.5 Zoning Consistency - Zoning ordinances tend to be very detailed, thus facilitating machine processing. Fresno County's successful use of EMIS for zoning consistency evaluations should hold for Santa Barbara County.

3.4 EMIS Documentation

Fresno County provided a large quantity of Systems Analyst/Programmer level documentation with the EMIS distribution tape.[2] This documentation is well organized and finely detailed. The system level documentation is adequate though somewhat intimidating due to the volume of information. No end user documentation is available, a situation that poses problems for effective use of EMIS on a production basis. However, Fresno County is in the process of developing an EMIS User's Manual. Judging by Fresno County's EMIS Programmer's Guide, their User's Guide should be extremely useful but would require some modification.

3.5 Output Products

The primary output products are the reports produced by EMIS. Since report content and format is controlled by programming, it is more appropriate to evaluate the use programming language. The syntax of the language is not sophistocated and is fairly awkward to use. However, it does work and provides a great deal of flexibility. The only drawback associated with the language is the need for a programmer to actually implement user requests.

The check plots produced by EMIS are adequate. A more in depth evaluation of the graphics routines recently developed by Fresno County is indicated.

3.6 Comparison with Other Geo-Based Systems

There are currently over two dozen general purpose geo-based information systems available today.[3,4] These systems are well documented, tested and are available publicly or privately through lease or purchase options. Most of these systems are written in FORTRAN IV and operate on a wide variety of computer configurations. In addition to the well tested and documented general purpose systems are numerous partially tested and applications dependent systems.[3]

In comparing EMIS with the "generic general purpose systems," five issues are identified.

- Source Language - EMIS is written in COBOL, the other systems in FORTRAN. COBOL provides superior I/O capabilities; moreover, County Data Processing Staff are much more experienced with COBOL.
- Output Products - EMIS is unique in offering a flexible report writing capability. The other geo-based systems currently pro-

vide superior graphic output.

- Documentation - The general purpose geo-based systems provide higher quality system level documentation and end user support.
- Permit Processing Capability - EMIS is the only geo-based system that provides a permit processing capability responsive to the California Laws of Planning and Zoning.
- Cost Factors - EMIS is less expensive to acquire than most other systems. Comparison of production processing costs with other systems is beyond the scope of this project.

3.7 Evaluation Summary

EMIS is the only geo-based system available for permit processing under the California State Laws of Planning and Zoning. Additionally, EMIS has capabilities for performing advanced planning work and modeling of proposed land changes. Because EMIS is "home-grown," it has all the attributes associated with software developed by a county:

- It has not benefited from the cross fertilization of ideas and software found in the academic or private sectors.
- The documentation is not polished as would be the case in a product from the private sector. The documentation is superior to many products developed by universities and research organizations.
- The programming was not developed with an eye toward transferability. The system definitely performs the types of tasks desired by Santa Barbara County, shows tremendous potential for both reducing costs and enhancing capabilities and can be installed on the County computer with minimal programming effort.

4.0 RECOMMENDATIONS

Given the overall positive evaluation of EMIS, the University recommends that Santa Barbara County should more closely examine all aspects of EMIS functioning. In order to alleviate the large budgetary committment that such an evaluation effort would entail, the University proposes a cooperative demonstration/evaluation project between the University and Santa Barbara County. This project would allow County personnel to intensively evaluate EMIS functioning on a portion of their jurisdiction. At the end of the project, the County would be able to make a decision on whether to proceed with full scale EMIS implementation, or to evaluate other alternatives.

The project is envisioned as a cooperative shared resource project. The University currently possesses the computer resources (coordinate digitizer, plotter, storage capacity and processing capability) as well as the technically trained personnel for using EMIS. Use of this equipment on the project would eliminate the need for the County to either lease or purchase equipment for testing/evaluation/demonstration purposes. Conversely, to avoid imposing a financial drain on the University, the County would furnish personnel to perform the actual work and obtain the additional benefit of personnel familiar with the actual operation of EMIS software and hardware.

4.1 Description of a Proposed Demonstration/Evaluation Project

The scope of work for the proposed project consists of five major tasks:

1) <u>Steering Committee Formation</u> - A steering committee composed of

County personnel from Administration, Building, Data Processing, D.E.R., Planning and Public Works, plus representatives from the University will be created. This committee will be responsible for finalizing the project plan and ensuring that the project progresses satisfactorily.

2) Cooperative Education Program - A series of seminars will be held at regular intervals throughout the project in order to provide a formal mechanism for the interchange of information between the County and the University. The steering committee will not be required to attend these meetings. The seminars are designed for operations level personnel and will cover the following types of topics:
   - Introduction to Spatial Data Processing
   - Description of County Permit Processing
   - EMIS Overview
   - Evaluation of manual vs automated costing/capacity
   - Integration of Remotely Sensed Data in the Planning Process

3) Cost Modeling - The University will develop a model to simulate EMIS implementation costs for Santa Barbara County. The model will be based on parameters supplied by the County and will allow County Management to examine potential costs associated with varying assumptions (e.g., a decrease in County revenues, an increase in land developmental activity, increased inflation rates, etc.).

4) EMIS Installation - EMIS will be installed on the University computer and a partial data base will be built for a small

portion of Santa Barbara County. This will provide County personnel with "hands on" experience with a geo-based system. The primary focus for building the local EMIS data base will be on classifying Landsat imagery (for determining vegetative cover), reformatting digital topographical data and preparing an interface between EMIS and census data. If feasible, data such as soil types, parcel information, and zoning designations will be collected.

5) Final Evaluation - A final evaluation report will be completed by the County personnel who attend the seminars in Task 2. Seminar #4 in Task 2 is envisioned as an organizational seminar which will serve to develop an outline for the format and content of the final report. This session should be scheduled at least two months prior to project completion to ensure an adequate lead time for report preparation. An oral presentation to the Board of Supervisors may also be appropriate.

5.0 ALTERNATIVES TO EMIS IMPLEMENTATION

The increasingly stringent planning legislation being enforced by Federal and State agencies, coupled with upward spiriling personnel costs and tighter controls on local government spending, forces counties to examine cost efficient alternatives to meeting their charters. Because the cost of data processing continues to decrease as the technology matures, more attention is being focused on automated solutions at a local level. These trends indicate that counties will eventually automate their planning functions;[5,6] the key question being whether it is appropriate for

Santa Barbara County to complete an in depth analysis of EMIS at this point in time.

5.1 Existing Manual Operation

The most straight-forward alternative to implementing EMIS consists of continuing with the current manual operation. In a conservative political climate this is the most palatable alternative; however, it carries a high risk potential in the long run. For instance, given the projected inflation rate for the whole economy, personnel costs will increase. To compensate for this rise, permit fees will rise, thus fueling local taxpayer discontent. Moreover, if the volume of permit processing increases, the County will have to streamline the current system, possibly cutting some of the assurance checks that maintain the current level of quality.

5.2 Work in Other Counties

The posture of Fresno, Orange and San Joaquin Counties in implementing EMIS lends support to an immediate Santa Barbara County effort. Generally, the work performed under AB 2560 (Imbrecht) by other counties in the state is not transferable to Santa Barbara. Special county level projects such as cadastral mapping in Alameda County are both too expensive and not of sufficient breadth to meet Santa Barbara County's needs. At a county level, EMIS is the only cost effective option open to Santa Barbara County.

In relation to the other counties in the State, an immediate implementation of EMIS provides a key benefit -- access to potential grant funding available to counties in the forefront of geo-base implementation. As noted in section 5.3 below, funds may be available to those counties demonstrating a strong committment to automating their planning functions. Conversely, a delayed EMIS implementation will ease Santa Barbara County's transition to automation by allowing the other counties in the State to develop end user documentation, learn the pitfalls of production work, etc.

5.3 State Level Support

In the past two years, many agencies at the state level have been implementing programs designed to support automation at a county level. Notable examples of this are the State Department of Conservation contributions to digital data capture and the "Needs Surveys" conducted by the Office of Planning and Research, Environmental Data Center. Immediately after the passage of Proposition 13, the state passed emergency legislation (AB 2560 Imbrecht) providing funds for counties to evaluate automated systems for accelerating the environmental review process. However, the pending ballot initiative to reduce state income will undoubtedly severely reduce state level support to counties, if passed.

A possible exception to the anticipated decline in state level support may be the passage of "AB 2827 Follow-up Funding" which will provide for continued development of automated systems at a county level. Since these funds will not be allocated from the state general funds, they will not be as susceptible to "budget cuts" if a cycle of decreased state funding is entered. In all probability though, if offered at all, these funds will only be offered once -- thus, supporting an immediate EMIS implementation strategy by Santa Barbara County.

5.4 Federal Level Support

Determining the potential levels of Federal support is always difficult. Many sources, such as the Department of Housing and Urban Development "Planning Assistance Grants" (701) are no longer available. Some programs such as the NASA funded "Vertical Data Integration Project"[7] and fallout from the 1974 Real Estate Settlement Procedures Act[8] are directed towards local agencies. However, most federal work on geo-based information systems has been directed toward large scale systems.[3,4,9,10] Furthermore, these systems are still not being released to local governments through outlets such as the National Technical Information Service (NTIS). On the other hand, the distribution of digital products developed at the Federal level has increased. Examples of this include the U. S. G. S. Digital Elevation Models, Digital Line Graphics and Defense Mapping Agency Elevation Data, Department of Commerce LANDSAT imagery and NTIS software products.

In summary, the Federal government will probably not provide direct county level support in terms of software or funding toward either developing or implementing local geo-based systems. The Federal government will continue to develop and improve digital products suitable for incorporation into county level data bases. Anticipated Federal support does not greatly affect the question of immediate or delayed EMIS implementation other than to suggest that no data which may interest the Federal government should be digitized immediately.

5.5 Private Sector

As noted in section 3.6 above, the private sector does not provide geo-based products suitable for county level permit processing other than EMIS (portions of EMIS were developed by VTN Geodata Systems, Inc. and the Battele Northwest Laboratory). Firms such as COMARC, Dames and Moore, and Environmental Systems Research Institute have captured data and implemented geo-based systems at a local level, but the focus has been primarily on advanced rather than current planning. Recently, several firms such as TEKTRONIX, Inc. and Henningson, Durham and Richardson have started offering software for cartographic display of planning data. The sophistication of these products should be monitored by the University. In the wake of Proposition 13, private sector products are generally too expensive for county governments. Recognizing the lack of a strong market at the county level, the private sector is not actively developing suitable technology.

5.6 Concluding Remarks

EMIS is currently the only geo-based system available which can meet Santa Barbara County's needs. Support from other counties, the State and the Federal government are dubious at best. The private sector currently does not provide alternative systems and, given the high cost associated with geo-based system development, will probably not respond to the limited market of counties in California. The University recommends that Santa Barbara County become familiar with the technology through the EMIS evaluation/demonstration program, but urges the County to recognize that the project can only succeed if the County provides full project support.

APPENDIX A - EMIS/LANDSAT INTERFACE

Local governments have always experienced difficulties in attempting to keep abreast of land use changes. The cost of maintaining trained personnel in the field for the purpose of recording change is prohibitive. On a theoretical level, government should be able to monitor change via the permit process. Realistically, county data files, such as Assessor land use codes or D.E.R. native vegetative maps, are frequently several years out of date for large areas.

LANDSAT imagery has been identified as a partial solution to this problem in that it is relatively inexpensive and can be obtained at regular temporal intervals. However, local government has not made extensive use of Landsat imagery, due primarily to the distribution of imagery on film products. Even when photographically enlarged, a film image does not provide either adequate resolution or sufficient registration control for most permit processing and current planning applications.

As more counties automate various portions of their planning and monitoring systems, a natural path is available for circumventing film medium problems -- inserting classified digital images directly into the automated data base. This technique allows the end users to completely control scaling and registration as well as providing the potential for automated modeling.

The LANDSAT-to-EMIS link is a specially written Video Image Communication and Retrieval (VICAR) system program that converts homogeneous clusters from a classified LANDSAT scene to a series of polygons for the EMIS data base. The polygon coordinates are appropriately scaled in state plane coordinates and labeled with a unique file type indicating the date of the scene and the classification category for each polygon. The polygons are inputted to the EMIS data base as a series of card images on magnetic tape and, in fact, appear to the EMIS system as normal digitized input.

Because this type of interface is a recent development and only a small number of counties have operational geobased systems, little or no information is available on the results of merging digital image data with the other components of a county date base. Hopefully, Santa Barbara County will take the lead in incorporating LANDSAT derived imagery into the planning process (via the EMIS system) in the proposed demonstration program.

REFERENCES

1) VTN Geo Data Systems, Inc., USAC - Des Moines Geoplanning Research and Demonstration Program, Van Nuys, CA, 1973.

2) Fresno County Planning Department, Environmental Management Information System Guide, Fresno, CA, 1979.

3) Information Systems Technical Laboratory, Comparison of Selected Operational Capabilities of Fifty-Four Geographic Information Systems, Ft. Collins, CO, 1977.

4) Computer Sciences Corporation, Automated Geographic Information Systems and LANDSAT Data: A Survey, Greenbelt, MA, 1978.

5) Public Policy Research Organization (UCI), Determinants of Support for Computerized Information Systems, Irvine, CA, 1976.

6) Public Policy Research Organization (UCI), County Computers: Growth, Usage and Management, Irvine, CA, 1976.

7) NASA Ames, "Vertical Data Integration Project of the California Integrated Remote Sensing System", Technical Applications Branch, NASA-Ames Research Center, Moffett Field, CA 94035.

8) Management Research Foundation, Box 218, Coronado, CA, 92110

9) Tomlinson, R. F., A Report to the Geography Program of the United States Geological Survey Concerning the Development of Geographical Data Handling Capability, Reston, VA, 1974.

10) Mitchell, W. B., K. E. Anderson, R. G. Fegeas and S. C. Guptill, USGS/IGU Special Data Handling Siminar #3, Reston, VA, 1976.

CHAPTER 3

PART 2

Watershed Runoff Study

Author: Frederick Mertz

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1.0 INTRODUCTION

1.1 Background

The introduction of intensive mechanized agriculture to the San Joaquin Valley floor region of Kern County has established it as the second leading agricultural county in the United States. However, only about one-half of the possible arable land is cropped, as sufficient water is not yet available for full agricultural development. The Kern River, with a discharge of approximately 615,000 acre feet per year, is the only major stream in the county. Water importation through the California Aqueduct and Friant-Kern Canal and tapping of groundwater sources is extensive. At present, Kern County agricultural interests use about two million acre feet of groundwater annually bringing about an overdraft of approximately 700,000 to 800,000 acre feet per year. If this overdraft continues, the economics of pumping groundwater for agriculture usage will become critical. Even with increasing amounts of imported water, the Kern River surface flow (i.e., runoff) remains an important parameter in the water supply/demand models in Kern County and reinforces the importance of maximizing its potential.

The Kern County Water Agency is mandated by the Kern County Board of Supervisors, under the authority of the California State Legislature, to provide storm runoff predictions for approximately 10,000 km^2 of mountainous watershed within the county. KCWA must develop storm runoff predictions for all watersheds in Kern County in order to:

- delineate flood plain boundaries which affect building standards for commercial and residential structures;
- establish building standards for specialized flood control facilities such as dams, debris basins, spreading ponds, etc.; and,
- provide base-line data for flood insurance.

KCWA currently uses the runoff prediction procedure developed by the United States Department of Agriculture's Soil Conservation Service (SCS). In this procedure runoff Curve Numbers (CN) are based on the soil-*cover* complex present in an area, and are the major drivers of the SCS runoff equation. The SCS runoff equation is:

$$Q = \frac{(P - 0.2S)}{(P + 0.8S)}$$

where: Q = runoff in inches

P = rainfall per storm

S = water storage factor equal to (1000/CN - 10)

CN = function of soil type, soil moisture, vegetation and density

KCWA uses a table-lookup approach for the determination of CNs for input to the SCS equation. The conventional method of obtaining vegetation cover data is by field survey, which is time consuming and expensive.

1.2 Study Area

The study area, as defined in last year's report (April 30, 1979), has been relocated and enlarged. The user agency requested the revised study area for the following reasons:

- certain lowland areas below unmapped watersheds within the area are slated for development;
- very few of the watersheds within this area are mapped for hydrologic purposes;
- extensive flood damage in this area and surrounding lowlands occurred during the 1977/1978 winter;
- there has been extensive wind damage of vegetated cover in watersheds included in the area.

The area under investigation includes twenty-four 7.5 minute United States Geological Survey (USGS) topographic quadrangles containing mountainous watersheds within Kern County (approximately 3500 sq. km.). This area, defined as high priority by KCWA, is shown in Figure 3-2.

The study area possesses a number of distinctive woody plant communities common to Mediterranean climates. These communities include: woodlands, evergreen scrubs (chaparral or hard chaparral), and drought-resistant shrubs (coastal sage or soft chaparral). Representative vegetation cover includes: chamise (*Adenostoma fasciculatum*), mountain mahogany (*Cercocarpus betuloides*), mountain lilac (*Ceanothus spp.*), and several species of annual and perennial grasses and conifers. Excepting *Quercus spp.*, there are few deciduous trees in the study area. Chaparral communities occur at all elevations within the study area (2000-4500 feet). The Mediterranean climate of the area produces favorable growing conditions during the winter and spring months. Annual/perennial grasslands and sage occur at

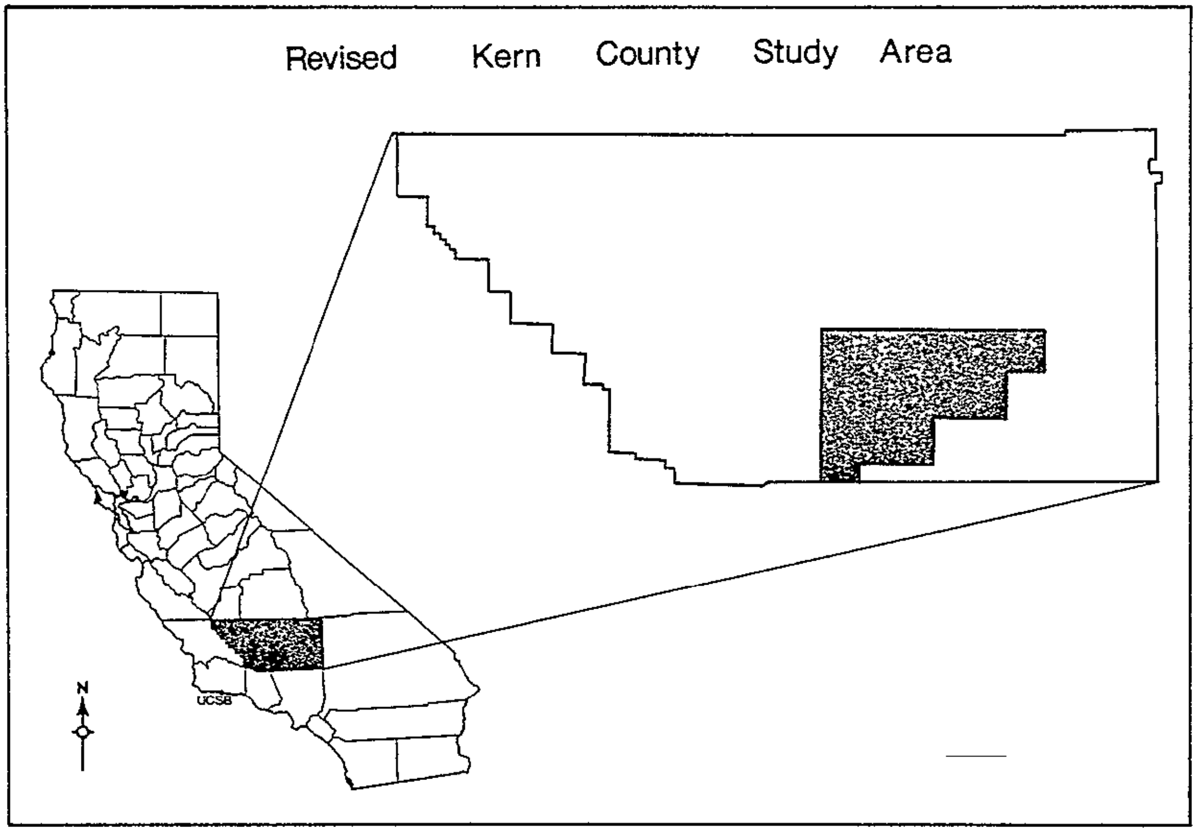

Figure 3-2. Location of Kern County Water Agency Watershed Runoff study area, Tehachapi Mountains, California.

lower elevations. Various types of woodland bisect chaparral brushfields in foothill areas (≈2000 feet) with riparian plant associations along canyon bottoms.

1.3 Conventional Methodology

Prior to implementing Landsat digital data collection methods, KCWA used "windshield surveys" in the watershed mapping procedures. The windshield survey technique employs one or two investigators driving throughout the study area noting, where possible, vegetation type, density, spatial extent, and location by drawing representative boundaries on USGS topographic base maps.

Certain limitations are inherent in terrestrial vegetation data collection surveys. For example, the primary investigative tool in the windshield survey technique is subjective analysis based on experience. Without realizing, an observer may "average" the scene by indicating only the primary vegetation type within an area of interest. This problem is compounded when density values are taken into consideration. For example, in a hillside of medium density grass with widely spaced oak trees, the investigator may designate the area as oak-poor, or grass-excellent instead of indicating true area composition. The practice of averaging is acceptable if the thresholds between classes/densities remain constant for each and all observers. Ground observations of the type discussed above have limited spatial accuracies due to the investigator's "look angle" and instantaneous field of view. With near grazing look angles (not uncommon) some areas may be hidden, and/or species/density boundaries may be inaccurately defined/mapped. Errors in the determination of vegetation density can also occur at this look angle.

The time required to conduct a survey of this magnitude is another limiting factor. If there is a long data collection period, seasonal species may die or become dormant and thus lead to watershed cover inconsistencies. Attempts to increase the temporal resolution of the study by increasing the number of observers often results in a higher probability of internal inconsistencies; the greater the number of observers, the greater the opportunity for variance in the sampling method.

The most significant limiting factor of a terrestrial survey of this nature is its cost. In 1978, KCWA estimated a cost of $630 to survey the area within a 7.5 minute quadrangle. This results in a total estimated cost of approximately $15,000 using conventional ground survey methods and 1978 costs. Due to drastically increased transportation expenses, employee wages, and supply costs, the 1978 figure is a very conservative estimate for our 1979/80 study. However, until we receive updated cost estimates from KCWA, the 1978 figures will be used for future comparison purposes.

2.0 APPROACHES AND PROCEDURES

2.1 Introduction

The image processing for this project was done in two modes, batch and interactive. Batch processing was accomplished using the Video Image Communication and Retrieval (VICAR) system implemented at UCSB on an ITEL AS/6. (VICAR was developed at the Jet Propulsion

Laboratory (JPL) in Pasadena, California.) Interactive processing at UCSB was performed utilizing software developed in house on a DEC PDP 11/45.

In addition to the above software, the Imaged Based Information System (IBIS), also developed at JPL, is now operational on the AS/6 at UCSB. With the combined VICAR/IBIS package, new capabilities in user-oriented processing are possible at UCSB. For example, provided with watershed boundaries, GRSU personnel could furnish KCWA with computer derived acreage estimates of vegetation types within each watershed. In addition, by using soils data as image datasets within IBIS, we would be capable of supplying KCWA with actual CN values, thereby greatly reducing the manpower required for their CN determination procedures.

For this project, digital analysis of the study area incorporates 8 possible data channels into the categorization routine. The presence of all 8 channels does not, however, infer their use. Only those channels determined significant to the classification of a specific species and/or those necessary to obtain acceptable accuracies will be used.

The 8 data channels are derived from Landsat MSS data. Channels one through four are the raw Landsat MSS data channels. (See Figures 3-3 to 3-6). Channels five through seven are the ratios MSS4/MSS5, MSS4/MSS7 and MSS5/MSS7. (See Figures 3-7 to 3-9). The ratio data appear to be significant in native vegetation studies according to research conducted by Ron J.P. Lyon of Stanford. (Reference 16).

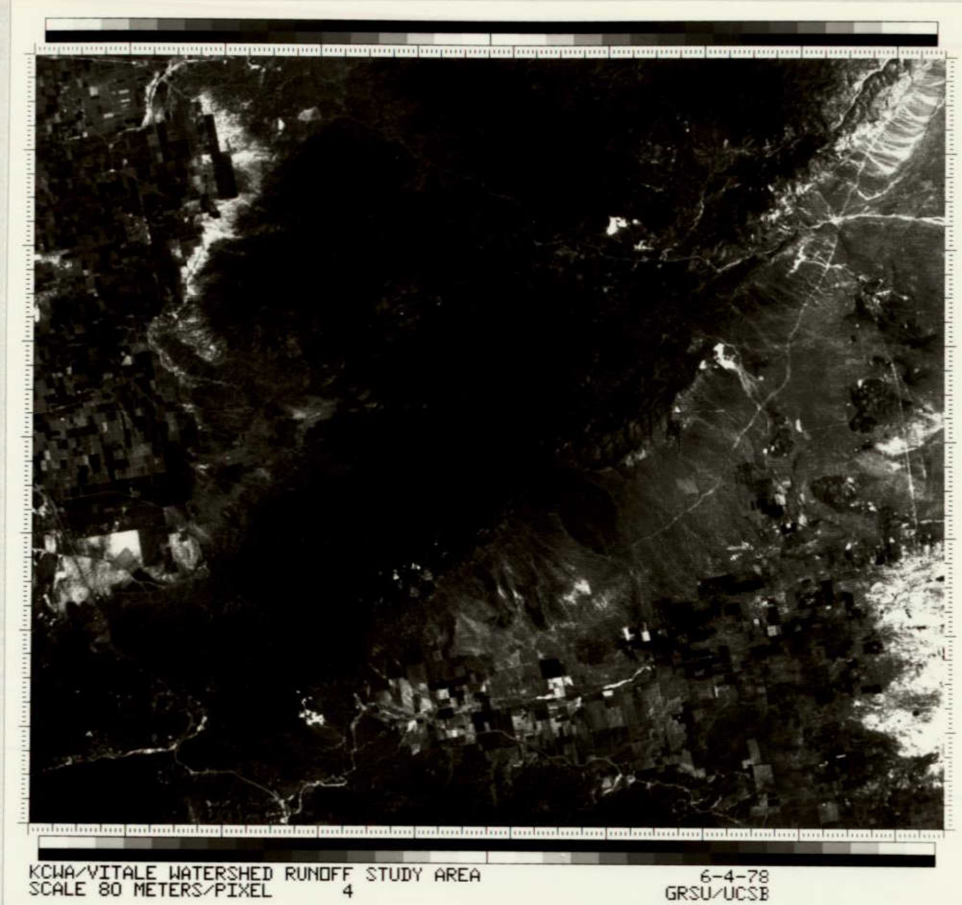

Figure 3-3. Kern County Water Agency Watershed Runoff Study Area, Tehachapi Mountains, California. Landsat MSS4, June 4, 1978.

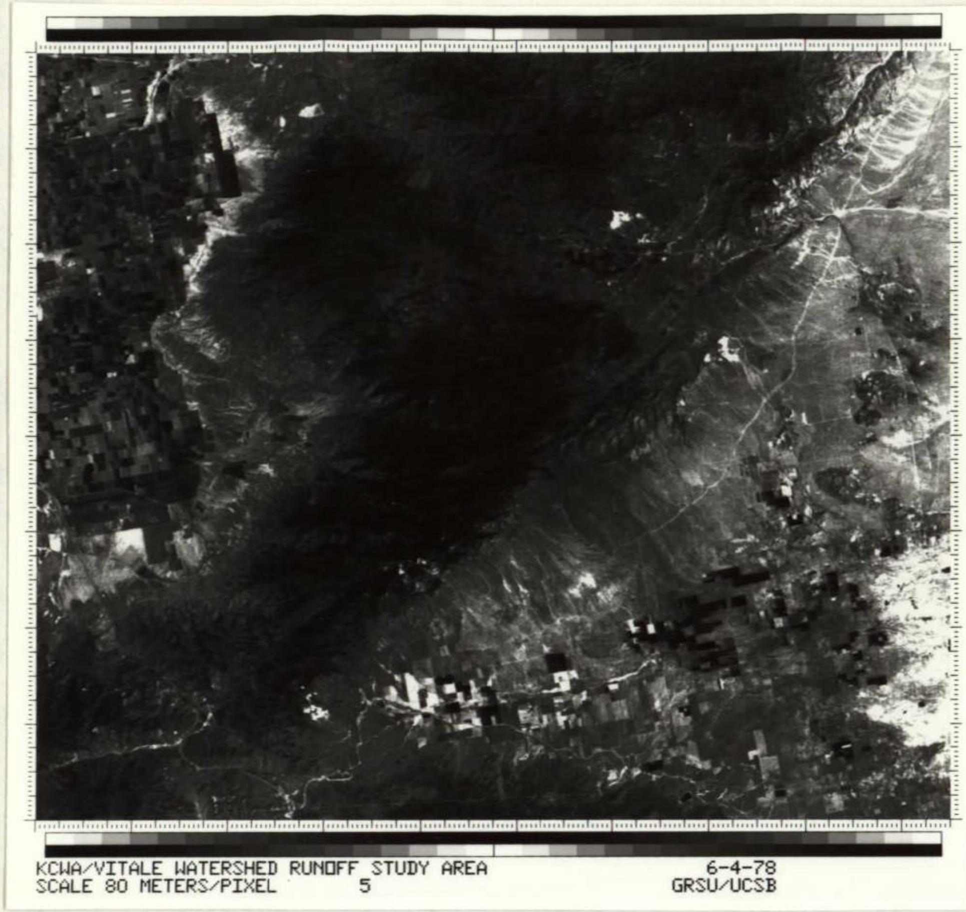

Figure 3-4. Kern County Water Agency Watershed Runoff Study Area, Tehachapi Mountains. Landsat MSS5, June 4, 1978.

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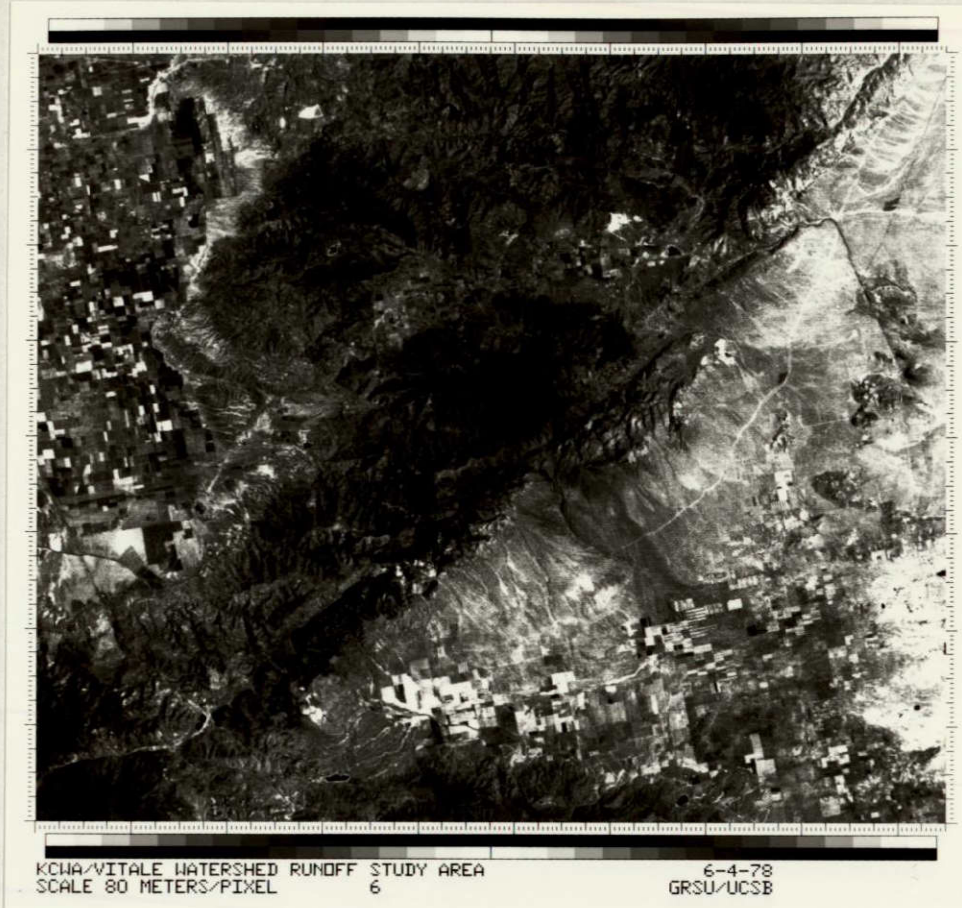

Figure 3-5. Kern County Water Agency Watershed Runoff Study Area, Tehachapi Mountains. Landsat MSS6, June 4, 1978.

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Figure 3-6. Kern County Water Agency Watershed Runoff Study Area, Tehachapi Mountains. Landsat MSS7, June 4, 1978.

Figure 3-7. Kern County Water Agency Watershed Runoff Study Area, Tehachapi Mountains. MSS4/MSS5, June 4, 1978. Note the differences within the native vegetation enhanced by this technique.

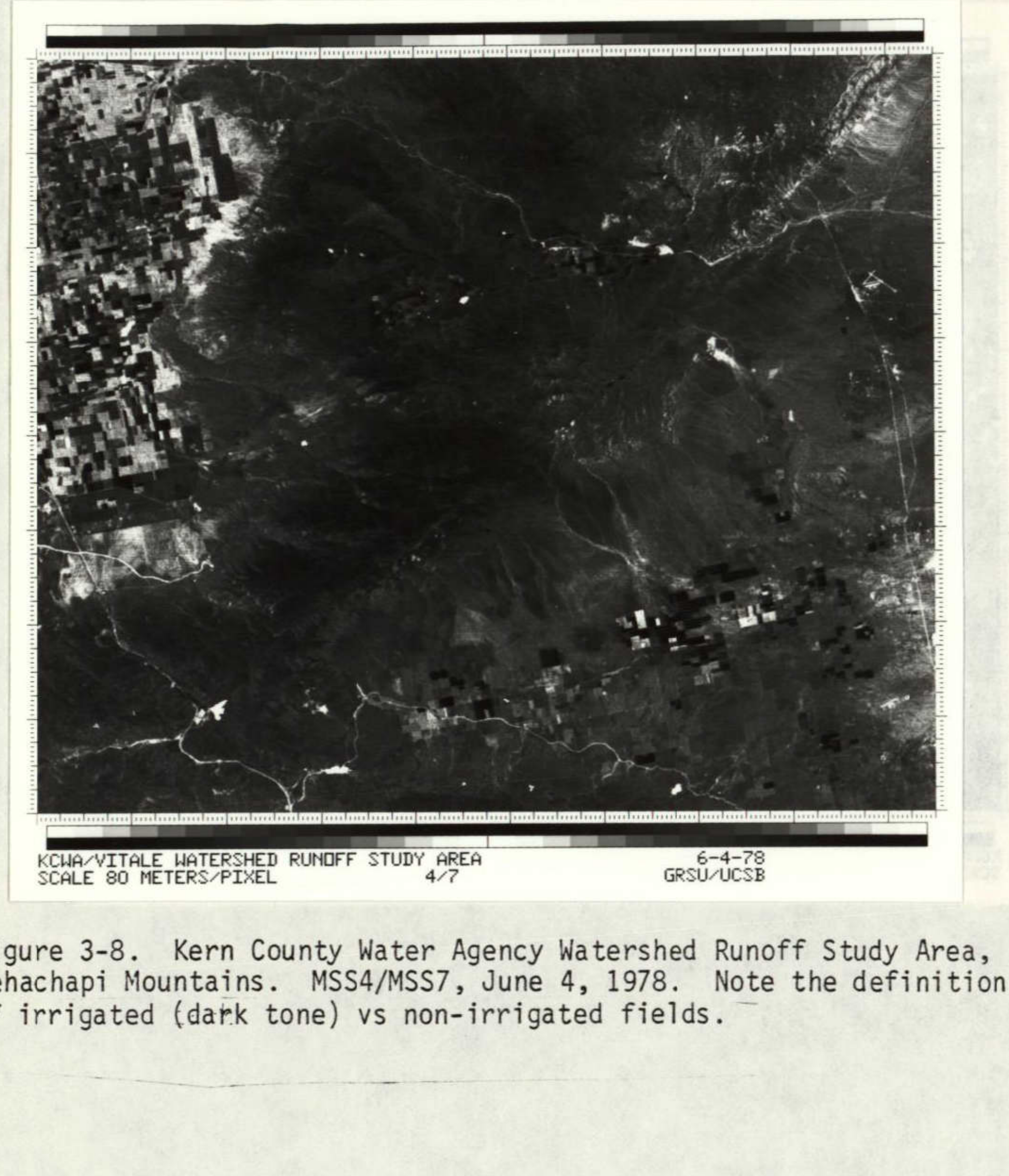

Figure 3-8. Kern County Water Agency Watershed Runoff Study Area, Tehachapi Mountains. MSS4/MSS7, June 4, 1978. Note the definition of irrigated (dark tone) vs non-irrigated fields.

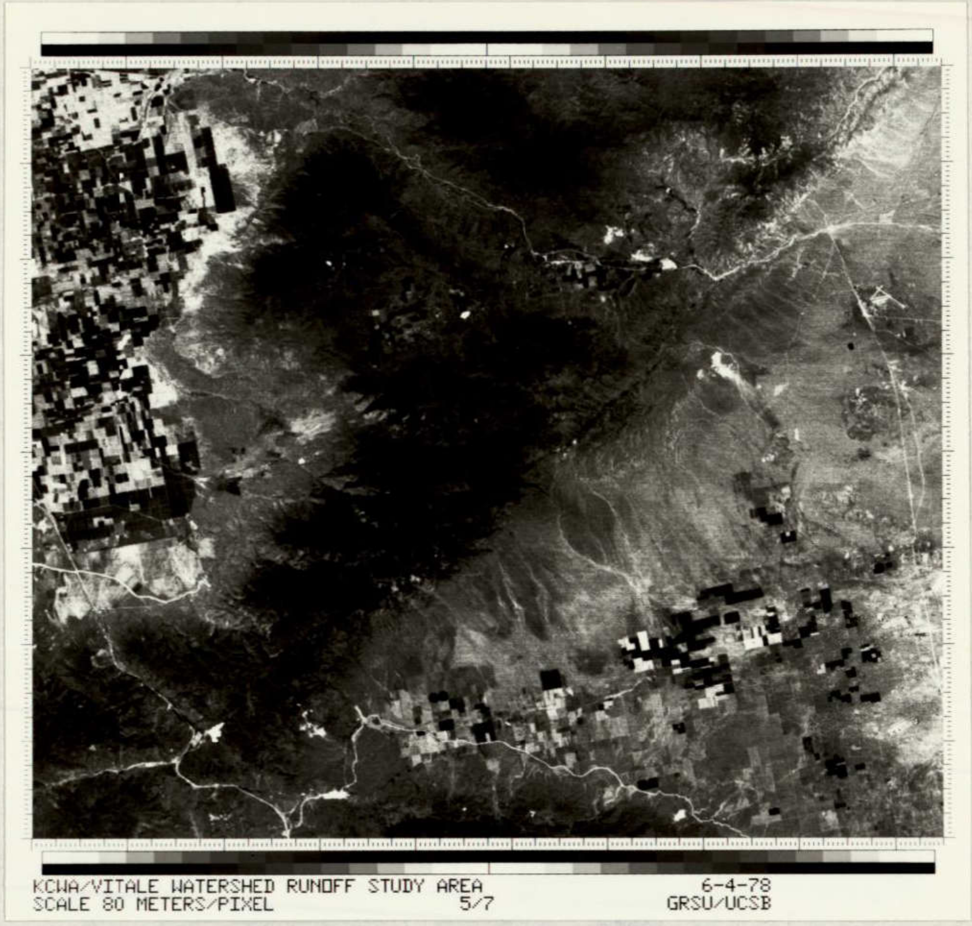

Figure 3-9. Kern County Water Agency Watershed Runoff Study Area, Tehachapi Mountains. MSS5/MSS7, June 4, 1978. Note the definition of vegetated vs non-vegetated areas.

Channel eight is a standard deviation image created from MSS7. (See Figure 3-10). Research conducted by Alan H. Strahler of UCSB (reference 34) has shown that the spatial texture information contained in the standard deviation image is valuable in the categorization of forested areas.

The purpose of initially analyzing 8 channels is for the determination of those which are significant to the desired categorized output. By defining the data channels unneccessary to the categorization procedure, fewer channels can be used while simultaneously maintaining high classification accuracies for the classes of interest. This data reduction procedure resulted in substantial processing and categorization cost reductions for this native vegetation study.

2.2 Digital Data Processing Techniques

The project processing sequence is diagrammed as Figure 3-11. The processing flow begins with Landsat CCT reformatting and satellite systematic error corrections using VICAR programs VSAR and VERTSLOG. Subscenes, corresponding to the predetermined study area, are then extracted from the 4 MSS datasets. Spectrally derived datasets (ratio and standard deviation images) are then created from the subscenes, using the appropriate software (RATIO AND TEXTURE).

Unsupervised statistics are calculated for 200 clusters using the datasets discussed above as input to the VICAR program USTATS. The clustered statistics data are then analyzed, aggregated and deleted using a variety of VICAR and non-VICAR programs (PDIST,

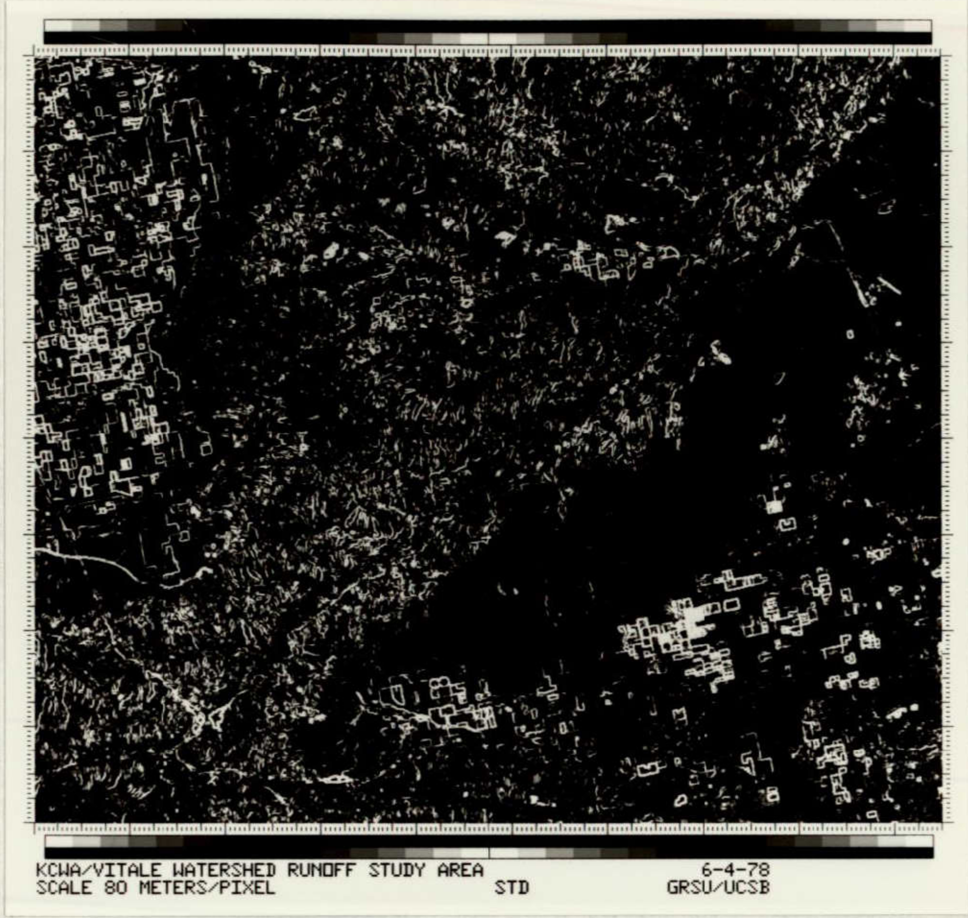

Figure 3-10. Kern County Water Agency Watershed Runoff Study Area, Tehachapi Moutains. Standard deviation image (created from MSS7), June 4, 1978. Note the enhancement of edges. This image proved useful for automated image registration of multiple dates for another project at GRSU/UCSB.

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KCWA/VITALE WATERSHED RUNOFF STUDY

VICAR PROCESSING SEQUENCE

Raw Landsat MSS Computer
Compatible Tapes (CCT's)

↓

Reformat and Perform
Systematic Corrections

↓

Extract Sub-images

↓

Create Sprectrally Derived
Channels (i.e. ratios)

↓

Generate Unsupervised
Statistics File

↓

Edit Statistics File
(aggregate and delete)

↓

Determine Optimum Channels
for Categorization

↓

Categorize

↓

Cluster Label and
Spatially Edit

↓

Locate Ground Control
Points (GCP's)

↓

Register Categorized Image
to Map Base

↓

Produce Desired Thematic
Map Overlays

Figure 3-11. This flow chart indicates the required processing steps for unsupervised categorization in the VICAR environment.

NTSYS, MEANLIST, and EDSTATS). This technique is known as spectral and/or statistical editing and is effective as a method of reducing the number of clusters to a reasonable number (less than 100), for the divergence and categorization procedures.

The optimum channels, of the 8 discussed earlier, are then selected for the categorization procedure using the VICAR program DIVERG, written at UCSB with support from this grant. The selected channels and the edited statistics file are input to the VICAR program FSTCLSPR for image classification. FSTCLSPR performs image categorization utilizing both parallelepiped (for speed and efficiency) and maximum likelihood (for resolving ambiguities).

A cluster labeling procedure follows using a color video display device and interactive software. MSS subscenes, containing vegetation types representative of the study area, are displayed for spatial location purposes while the categorized image is overlayed as a binary mask. Individual and/or groups of clusters (referenced by cluster number) are labeled based on airphoto interpretation and/or field surveys. This technique is known as cluster labeling and/or spatial editing and is essential to the accurate categorization of an area.

Using Ground Control Points (GCP's) whose precise geodetic and image coordinates have been determined, and the VICAR rectification routine GEOMA, a planimetrically rectified categorized Landsat image output product at any chosen scale is produced. Our map products correspond to the existing USGS topographic base maps used operationally by KCWA at scales of 1:24,000 (where available) and 1:62,500.

3.0 TASKS PERFORMED SINCE LAST REPORT

3.1 Logistics

3.1.1 Study Area Definition - Discussion and reevaluation of the project goals and output products, with substantial input by the user agency (KCWA), yielded a revised and enlarged study area.

3.1.2 Date Selection - The above discussions led to the selection of a timely image date for the inclusion of recent flood and wind damage. The image date chosen was 6/4/78.

3.2 Image Processing

3.2.1 Data Reformatting and Correction - Data reformatting of the computer compatible tapes (CCT's), image data calibration and correction of the systematic errors was accomplished using the VICAR programs VSAR and VERTSLOG.

3.2.2 Subscene Extraction - Sub-areas of the image datasets were extracted and masked to include only the mountainous regions of the study area using the VICAR program PSAR. By excluding unwanted areas, costs are reduced for clustering and categorization procedures.

3.2.3 Creation of Spectrally Derived Datasets - Ratio channels were created using the VICAR program RATIO. The texture channel was calculated using the VICAR subroutine TEXTURE.

3.2.4 Cluster Generation - The unsupervised statistics file was created via the VICAR program USTATS for 200 clusters.

3.2.5 Statistical Editing - The statistics file output from USTATS was then modified using the non-VICAR programs PDIST, NTSYS, and MEANLIST, and the VICAR program EDSTATS. This editing procedure allowed us to modify the statistics dataset so that fewer than 100 clusters remained, while still remaining confident of the cluster representation of the image data.

3.2.6 Dataset Selection - Dataset selection for input to the categorization procedure was made using a divergence and/ or separability measure.

Divergence values for the first statistics dataset indicated that the texture channel was the most powerful discriminator of the clusters. However, the texture image was included in the clustering run because of its capabilities for defining edges and continuous areas, not as the primary discriminating channel. Indications are that the spatial variations (i.e. rate of change of vegetation units, slope orientations, soil types, etc.) for the KCWA study area are much higher than the spatial frequencies of forrested areas where the technique was developed. This is due to the relationship between sensor spatial resolution and spatial frequencies prevelant in the study area.

The texture data disrupted the clustered output by its high variance and spatial colinearity, and therefore, was dropped as a data channel. The clustered dataset using texture was so 'fractured' and 'fragmented' that USTATS (and all the necessary steps which follow) was rerun without the texture image as input.

Channels chosen for the categorization procedure were MSS5, MSS7, MSS4/MSS5 and MSS5/MSS7.

- MSS5/MSS7 is known to define vegetated vs. non-vegetated areas, as can be seen in Figure 3-9. When combined with MSS5 and MSS7, the MSS5/MSS7 adds positive covariance information to the classifier. (USTATS does not compute covariance). A color composite of MSS5 (green), MSS7 (red) and MSS5/MSS7 (blue) appears as Figure 3-12.
- MSS4/MSS5 was included because it enhances subtle differences within the native vegetation as seen in Figure 3-7.
- MSS5 and MSS7 proved more powerful than MSS4 and MSS6 in the divergence analysis, hence their inclusion.

3.2.7 Image Categorization - Using the VICAR program FSTCLSPR and the aforementioned datasets, image categorization was performed for 41 clusters. (The 41 clusters were obtained by statistically editing the 200 clusters produced by USTATS.)

3.2.8 Geometric Transformation - Over 50 ground control point locations were located in image space and on a UTM (Universal Transverse Mercator) grid.

Image coordinates were located using interactive software and the video display device. UTM coordinates were located using USGS 7-½ minute quadrangles (1:24,000) and a coordinate digitizer interfaced with interactive software.

Functions are currently under development for transformation of UTM coordinates to a lineprinter grid. KCWA has re-

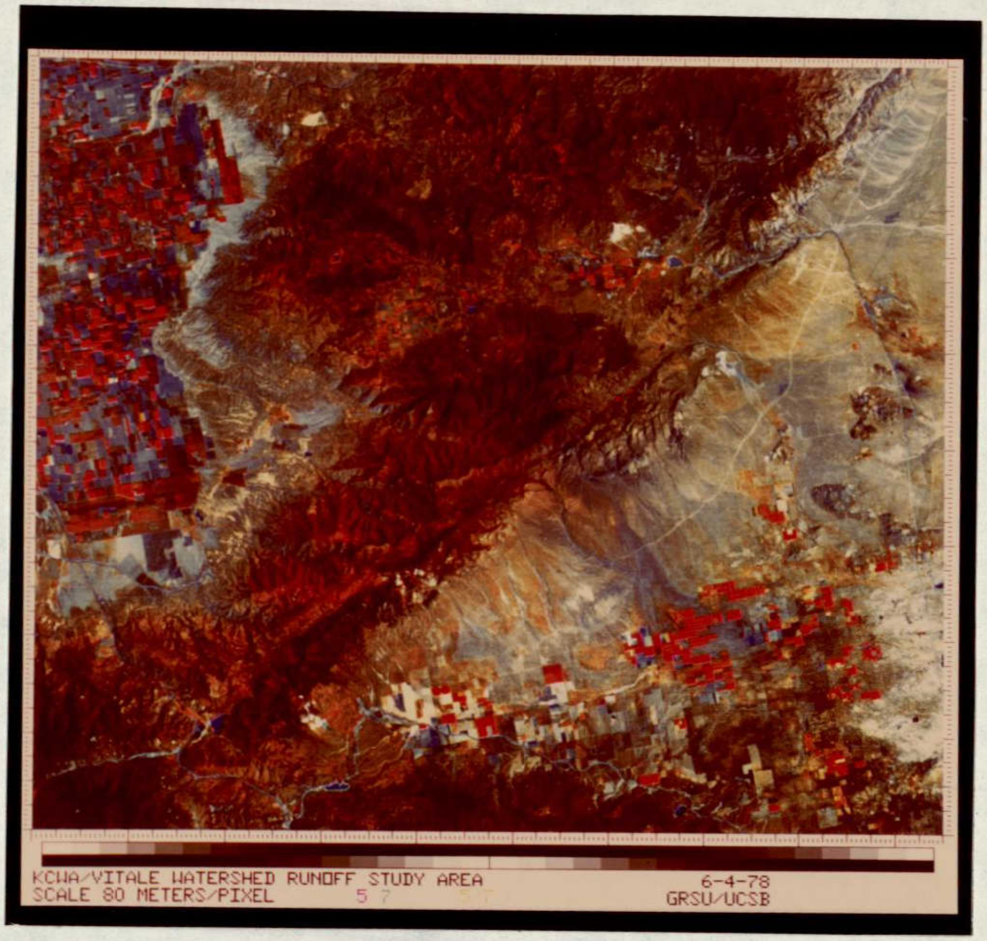

Figure 3-12. Kern County Water Agency Watershed Runoff Study Area, Tehachapi Mountains. Color composite of MSS5 (green), MSS7 (red), and MSS5/MSS7 (blue), June 4, 1978. These three channels were combined with MSS4/MSS5 in the categorization procedure. Note the enhancement of water bodies and bare fields, and the enhanced definition of native vegetation types and/or distribution densities.

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quested lineprinter output at 1:24,000 for 7-½ minute quad sheet overlays.

3.2.9 Data Analysis - GRSU personnel will analyze the digitally categorized data for categorization and registration accuracies.

Image classification accuracies will be determined by a random sample, and registration accuracies will be estimated by a feature overlay procedure on a quad by quad basis.

3.3 Software Development

A new VICAR program, DIVERG, was written for optimum channel selection and class/cluster statistical editing procedures. The development of DIVERG was partially supported by this grant, with the remaining time being donated by the author. The source and compiled versions of DIVERG have already been released to JPL and Texas A & M University (TAMU). Additional releases will be made upon request. DIVERG documentation is included as Appendix B.

3.4 User Interaction/Support

3.4.1 Watershed Mapping - The user agency (KCWA) has provided complete mapping of three watersheds within the study for comparison purposes. These maps include soil data in addition to the vegetation types/densities.

3.4.2 Curve Number Determination - KCWA has calculated and supplied GRSU with CN's for the three watersheds described above. This data is important for subsequent analysis of the techniques developed by this project.

3.4.3 Remote Sensing Education - KCWA paid for one member of its staff to attend a 3-day short course on remote sensing. The course was held in January at UCSB.

3.4.4 Travel - KCWA personnel have set up and attended project meetings held at GRSU/UCSB. These meetings have allowed GRSU staff members to fully introduce remote sensing techniques to KCWA personnel.

3.4.5 User Funding Support - KCWA has allocated $500.00 for future image processing provided acceptable results are obtained from the present study. Future work would include digital mapping of other high priority watersheds within the county.

4.0 TASKS TO BE COMPLETED

4.1 Image Processing

4.1.1 Cluster Labeling - Categorized output from the FSTCLSPR is to be cluster labeled. 41 clusters are currently present. KCWA personnel will provide field surveys, and assist with the interactive cluster labeling procedures.

4.1.2 Geometric Transformation - GRSU personnel will finalize the geometric transformation necessary to convert UTM coordinates to a lineprinter grid.

4.1.3 Map Production - Lineprinter output corresponding to USGS 7-½ minute quadrangles will be produced for the categorized, rotated, rectified and transformed image. These outputs are suitable, and have been requested by the user.

4.2 User Interaction/Support

4.2.1 Watershed Delineation - KCWA personnel will map watershed boundaries via either of the following methods:

- conventional - drawing boundaries on 7½ minute quads and/or quad overlays
- digital - using the digitizing procedures/equipment at GRSU/UCSB for mapping watersheds on the digital data base (image). KCWA has expressed a sincere interest in following up this suggestion.

4.2.2 Land Cover Estimates - KCWA will compute area 1 estimates of vegetative cover types within predetermined watershed boundaries using one of the approaches below:

- conventional - hand count each and every pixel within the watershed
- digital - using the VICAR program CROSSTAB, precise counts of each class within the watershed will automatically be determined. KCWA is very interested in pursuing this technique.

4.2.3 User Example/Analysis - KCWA will provide GRSU staff with examples of data usage. Additionally, KCWA will analyze the data produced for acceptability and possible model calibration procedures.

4.3 Project Analysis

GRSU personnel will obtain examples of KCWA's use of remote sensing derived inputs for analysis, evaluation and documentation purposes, with regard to fulfillment of expected project goals.

APPENDIX B

Software Documentation

VICAR PROGRAM DIVERG

Written by: F. C. Mertz
GRSU, UCSB
Summer 1979

Funding support for development of this software was from NASA grant # NSG-7220 (VITALE).

Current Cognizant Programmer: F. C. Mertz

Revision: 11/29/79

PURPOSE

'DIVERG' is a VICAR applications program which calculates the separability of class pairs, and the average, minimum, and maximum divergence values for single channels or multiple channel combinations. Output of the separability matrix is optional (see params) while the divergence values for each channel combination are output by default.

Comparison of the divergence values for specific channel(s) gives an indication of the relative information content of the data channel(s) under investigation. If certain channels do not add significant information they should be excluded from the classification/categorization procedure in order to reduce costs and improve accuracy performance. The separability matrix allows the user to locate confusion classes on a channel by channel, or channel combination basis. Separability and divergence values are scaled such that a divergence/separability index value of 180 appears as '100' on output. This value is merely a scaled indicator of the separability measure and has not yet been tested or linked to probabilities of correct classification.

EXEC STATEMENT FORMAT

EXEC,DIVERG,STAT,*,{size},PARAMS
where EXEC and DIVERG are keywords

STAT Input data set containing 'training' statistics. This can be the output from VICAR programs 'STATS', 'USTATS', or 'EDSTATS'.

	Standard VICAR output data set to lineprinter.
SIZE	Standard VICAR size field (optional and unused).
PARAMS	Standard VICAR parameter field.

PARAMETER FORMAT

'BAND', N1,N2...	Denotes that channel(s) N1,N2,... are to be used in the divergence calculation. Note: these channel numbers (N1,N2..) refer to the channel locations in the statistics file only, and do not necessarily correspond to sensor bands. Limitations: Maximum number of channels is 25. Default = All channels in the input stats file.
'SEPA'	Denotes that the separability matrices are to be printed for each channel combination. Limitation: Maximum number of classes is 100. Default = No output of the separability matrix.
'COMB',N3	Denotes that combinations of channels up to and including N3 at a time are to be performed. Note: This value should not be greater than the number of channels being used. Default = 3.
'FCLA',N4	Denotes that the first class to be used in the calculations is to be N4. Limitation: Maximum number of classes is 100. Default = 1.
'LCLA',N5	Denotes that the last class to be used in the calculations is to be N5. Limitation: Maximum number of classes is 100. Default = Last class in the stats file.

OPERATION OF DIVERG

'DIVERG' calculates the divergence (or separability) of class pairs J(i,j) using the formula:

$$J(i,j) = \tfrac{1}{2}\,\mathrm{tr}\,(\Sigma_{(i)} - \Sigma_{(j)})\,(\Sigma^{-1}_{(j)} - \Sigma^{-1}_{(i)}) + \tfrac{1}{2}\,\mathrm{tr}\,(\Sigma^{-1}_{(i)} + \Sigma^{-1}_{(j)})\,(\bar{\mu}_{(i)} - \bar{\mu}_{(j)})\,(\bar{\mu}_{(i)} - \bar{\mu}_{(j)})^{T}$$

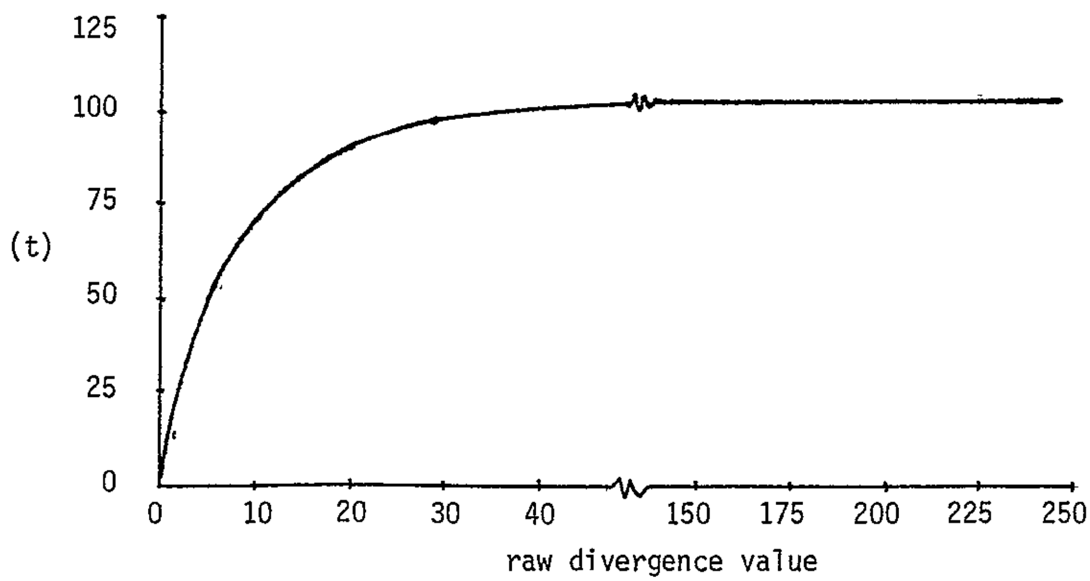
where: Σ = variance covariance matrix
u = vector of class means
tr = trace

'STATS', 'USTATS', or 'EDSTATS' data sets are compatible as input to 'DIVERG'. All or selected channels from the input data set are used for the separability and divergence calculations. The class pair separability matrix is stored for each channel or set of channel combinations but is only output when the 'SEPA' parameter is used. The separability values for each class combination are transformed values ranging from 0 to 100. The separability and divergence values output by 'DIVERG' are transformed values which saturate at 100. The transformation expression follows.

$$div\ (t) = 100 * (1-\exp(-div/8))$$

where: div (t) = transformed divergence
div = untransformed (raw) divergence

A graph of the transformation appears below.



A raw divergence value of 180 or greater causes the transformed divergence to saturate at 100. The average, maximum and minimum divergence values for each channel or set of channel combinations are calculated from the separability matrix and, therefore, are also transformed values.

Matrix inversion procedures within 'DIVERG' require a positive definite matrix. These calculations require non-zero variances for all channels and all classes. A zero variance can occasionally occur with very small training sets. If a variance of zero is read, it will be automatically reset to 0.1 for the divergence calculations.

REQUIREMENTS

'DIVERG' requires approximately 240K of core regardless of the input data set size. Time and line requirements have not yet been determined.

SOFTWARE SUPPORT REQUIREMENTS

'DIVERG' was written utilizing IMSL (International Mathematical and Statistical Library, Inc.), Edition 7. IMSL subroutines called by 'DIVERG' are listed below. NOT listed below are the programs and/or subroutines called by IMSL routines described.

Name	Purpose
LINV3P	in place inverse, positive definite matrix (symmetric storage mode).
VCVTSF	storage mode conversion of matrices (symmetric to full).
VCVTFS	storage mode conversion of matrices (full to symmetric).
VMULSF	matrix multiplication (symmetric by full matrices).
VMULSS	matrix multiplication (symmetric storage mode).

REFERENCES

Goodenough, David, and P. M. Narendra, 1976, Feature Subset Selection In Remote Sensing. Presented at Milwaukee Symposium on Automatic Computation and Control.

Kullback, Solomon, 1959, Information Theory and Statistics. Dover Publications.

Shlien, Seymour, David Goodenough, 1973, Automatic Interpretation of ERTS-A Imagery Using the Macimum Likelihood Decision Rule. Canada Centre for Remote Sensing Research Report 73-2.

EXAMPLES

```
FIND,EDSTAT3
E,DIVERG,EDSTAT3,,,P1
P,P1
 BAND 2,4,6,7
 COMB 4
 FCLAS 10
 LCLAS 25
 SEPA
END
```

This example produces class pair separability matrices for classes 10 through 25 for channels 2,4,6 and 7. The channel combinations are taken up to 4 at a time. A sample output appears below.

CLASS PAIR SEPARABILITY MATRIX PART 1 OF 1
CHANNELS 2

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
10 *	0	100	99	98	99	98	68	48	67	90	1	93	99	100	99	99
11 *	100	0	97	100	100	100	100	100	100	100	100	100	100	81	100	100
12 *	99	97	0	94	58	93	95	99	97	94	99	90	42	3	38	38
13 *	98	100	94	0	100	85	100	100	100	99	100	99	100	100	100	100
14 *	99	100	58	100	0	49	83	99	87	69	99	58	1	74	3	3
15 *	98	100	93	85	49	0	100	100	100	99	100	99	100	100	100	100
16 *	68	100	95	100	83	100	0	77	0	9	67	15	82	99	67	67
17 *	48	100	99	100	99	100	77	0	100	100	99	100	100	100	100	100
18 *	67	100	97	100	87	100	0	100	0	11	64	18	87	99	75	75
19 *	90	100	94	99	69	99	9	100	11	0	100	99	100	100	100	100
20 *	1	100	99	100	99	100	67	99	64	100	0	93	99	100	99	99
21 *	93	100	90	99	58	99	15	100	18	99	93	0	100	100	100	100
22 *	99	100	42	100	1	100	82	100	87	100	99	100	0	62	2	2
23 *	100	81	3	100	74	100	99	100	99	100	100	100	62	0	100	100
24 *	99	100	38	100	3	100	67	100	75	100	99	100	2	100	0	0
25 *	99	100	38	100	3	100	67	100	75	100	99	100	2	100	0	0

DIVERGENCE VALUES			CHANNEL COMBINATIONS
AVG	MIN	MAX	
82	0	100	2 ~~3-60~~

EXAMPLES (cont)

This example produces a tabel of average, minimum, and maximum divergence values for classes 10 through 25. Channels 1,2,4,5,6, and 7 are taken up to 3 at a time (default value for COMB). A sample output appears below.

```
FIND,EDSTAT3
E,DIVERG,EDSTAT3,,,P1
P,P1
 BAND 1,2,4,5,6,7
 FCLAS 10
 LCLAS 25
END
```

DIVERGENCE VALUES			CHANNEL COMBINATION.		
AVG	MIN	MAX			
88	0	100	1		
84	0	100	2		
81	0	100	4		
88	0	100	5		
85	0	100	6		
87	0	100	7		
97	29	100	2	1	
96	33	100	4	1	
98	52	100	5	1	
98	48	100	6	1	
97	40	100	7	1	
94	31	100	4	2	
97	28	100	5	2	
96	22	100	6	2	
96	32	100	7	2	
96	21	100	5	4	
95	18	100	6	4	
95	18	100	7	4	
97	39	100	6	5	
97	39	100	7	5	
96	27	100	7	6	
99	69	100	4	2	1
99	74	100	5	2	1
99	68	100	6	2	1
99	79	100	7	2	1
99	55	100	5	4	1
98	43	100	6	4	1
99	63	100	7	4	1
99	82	100	6	5	1
99	88	100	7	5	1
99	62	100	7	6	1
98	57	100	5	4	2
98	46	100	6	4	2
99	65	100	7	4	2
99	83	100	6	5	2
99	68	100	7	5	2
99	64	100	7	6	2
99	83	100	6	5	4
99	71	100	7	5	4
99	63	100	7	6	4
99	62	100	7	6	5

REFERENCES

1) Ambaruch, R., and J. W. Simmons, 1974. A study of remote sensing as applied to regional and small watersheds. Final Report, NASA Contract No. NAS5-21942, Volumes 1 and 2, International Business Machines, Huntsville, Alabama.

2) Aron, G., A. C. Miller, and D. F. Lakatos, 1977. "Infiltration Formula Based on SCS Curve Number," Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers.

3) Barbour, M. G., J. Major, (Eds.) 1977. "Terrestrial Vegetation of California," John Wiley and Sons, Inc., New York, New York.

4) Blanchard, B. J., 1973. "Measuring Watershed Runoff Capability with ERTS Data," Third Earth Resources Technology Satellite-1 Symposium, Vol. I: Technical Presentations Section B.

5) Blanchard, B. J., 1975. "Remote Sensing Techniques for Prediction of Watershed Runoff," Paper w-15, NASA Earth Resources Survey Symposium, Houston, Texas.

6) Bryant, N., C. R. Paul, A. J. Landini, R. W. Bannister, and T. L. Logan, 1977. LUMIS: Land Use Management Information System, Coordinate Orientated Program Documentation, JPL SP 43-33, NASA, 1976.

7) Bryant, N. A., 1976. "Integration of Socioeconomic Data and Remotely Sensed Imagery for Land Use Applications," in: Proceedings. CAL TECH/JPL Conference on Image Processing Technology Data Sources and Software for Commercial and Scientific Applications, CALTECH, Pasadena, California, Nov. 3-5, 1976.

8) Bryant, N. A., and A. L. Zobrist, 1976b. "IBIS: A Geographic Information System Based on Digital Image Processing and Image Raster Datatype," in: Symposium on Machine Processing of Remotely Sensed Data, LARS, Purdue University, West Lafayette, Indiana, June 29, 1976.

9) Driscoll, R. S., R. E. R. Francis, J. A. Smith, and R. A. Mead, 1974. "ERTS-1 Data for Classifying Native Plant Communities - Central Colorado." in: Proceedings Ninth International Symposium on Remote Sensing of Environment, April 1974, Vol. 2, Center for Remote Sensing Information and Analysis, Environmental Research Institute of Michigan, Ann Arbor.

10) Hoffer, R. M., 1976. Techniques and Applications for Computer-Analysis of Multispectral Scanner Data, LARS Information Note 062276, Laboratory for Applications of Remote Sensing (LARS), Purdue University, West Lafayette, Indiana.

11) Hoffer, R. M., and staff, 1975. Natural Resource Mapping in Mountainous Terrain by Computer Analysis of ERTS-1 Satellite Data, Research Bulletin 919 (LARS Information Note 061575), Laboratory for Applications of Remote Sensing and the Agricultural Experiment Station, Purdue University, West Lafayette, Indiana.

12) Jackson, T. J., R. M. Ragan, N. W. Fitch, May 1977. "A Test of Landsat-Based Urban Hydrologic Modeling," Journal of the Water Resources Planning and Management Division, ASCE, Vol. 103, No. WRI.

13) Jackson, T. J., R. M. Ragan, R. P. Shubinski, July 1976. "Flood Frequency Studies on Ungaged Urban Watersheds Using Remotely Sensed Data," Proceedings, National Symposium on Urban Hydrology, Hydraulics and Sediment Control, Lexington, Kentucky.

14) Jackson, T. J., Nov. 1975. "Computer-Aided Techniques for Estimating the Percent of Impervious Area from Landsat Data," Proceedings of the Workshop on Environmental Applications of Multispectral Imagery, American Society of Photogrammetry, Fort Belvior, VA.

15) Jackson, T. J., R. M. Ragan, R. H. McCuen, 1975b. "Land Use Classification for Hydrologic Models Using Interactive Machine Classification of Landsat Data," Paper w-14, NASA Earth Resources Survey Symposium, Houston, Texas.

16) Lyon, R. J. V. 1978, personal communication.

17) McKeon, J. B., L. E. Reed, R. H. Rogers, R. M. Ragan, O. C. Wiegand, March 4, 1978. "Landsat Derived Land Cover and Imperviousness Categories for Metropolitan Washington: An Urban/Non-Urban, Computer Approach," Proceedings, ASP/ASCM Annual Meeting, Washington, D.C.

18) Miller, L. D., C. Tom, K. Mualchawee, March 1977. "Remote Sensing Inputs to Landscape Models which Predict Future Spatial Land Use Patterns for Hydrologic Models," Invited Paper, United Nations Water Conference, Technical and Scientific Sessions on Water Resources, Mar del Plaza, Argentina.

19) Ragan, R. M., V. V. Salomonson, April 1978. "The Definition of Hydrologic Model Parameters Using Remote Sensing Techniques," Proceedings of the 12th Symposium on Remote Sensing of Environment, Environmental Research Institute of Michigan, Ann Arbor, Michigan.

20) Ragan, R. M., April 1977. "Utilization of Remote Sensing Observations in Hydrologic Models," Proceedings of the 11th Symposium on Remote Sensing of Environment, Environmental Research Institute of Michigan, Ann Arbor, Michigan.

21) Ragan, R. M., T. J. Jackson, W. N. Fitch, R. P. Shubinski, 1976. "A Comparison Between Conventional and Landsat-Based Hydrologic Modeling the Four Mile Run Case Study," NASA Report #NSG 5017.

22) Ragan, R. M., T. J. Jackson, July 1976b. "Hydrograph Synthesis Using Landsat Remote Sensing and the SCS Models," NASA TM-X -913-76-161, Goddard Space Flight Center.

23) Ragan, R. M., T. J. Jackson, Dec. 1975. "Use of Satellite Data in Urban Hydrologic Models," Journal of Hydraulics Division, American Society of Civil Engineers.

24) Rango, A., August 1975. "Applications of Remote Sensing to Watershed Management," Proceedings, ASCE Irrigation and Drainage Symposium on Watershed Management, Logan, Utah.

25) Salomonson, V. V., R. Ambaruch, A. Rango, J. P. Ormsby, April 1975. "Remote Sensing Requirements as Suggested by Watershed Model Sensitivity Analysis," Proceedings 9th International Symposium on Remote Sensing of Environment, ERIM, Ann Arbor, Michigan.

26) Salomonson, V. V., R. Ambaruch, A. Rango, J. Ormsby, October 6-10, 1975. "The Suitability of Remote Sensing Data for Input to Numerical Watershed Models," Proceedings of the 10th International Symposium on Remote Sensing of Environment, ERIM, Ann Arbor, Michigan.

27) Sasso, Robert R., F. Mertz, J. E. Estes, S. P. Kraus, 1978. "Comparative Results of Conventional and Digital Land Cover Collection Methodologies for Input to Hydrologic Modeling," Proceedings of the 12th International Symposium on Remote Sensing of Environment, Manila, Philippines, Environmental Research Institute of Michigan, Ann Arbor, Michigan.

28) Sasso, Robert R., F. Mertz, J. E. Estes, 1978b. " A Comparison of Conventional and Landsat II Digital Land Cover Data Collection Methods for Input to Hydrologic Modeling," The Economics of Remote Sensing Information Systems, January 1978, San Jose, California.

29) Sasso, R. R., J. R. Jensen, John E. Estes, 1977. "Automatic Image Processing of Landsat II Digital Data Watershed Runoff Prediction," Proceedings of the 11th International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan.

30) Slack, R. B., 1977. "Landsat Data As A Basis for SCS Curve Numbers," Contribution of the Science and Education Administration, USDA, Southern Region.

31) Soil Conservation Service, 1964, 1972. National Engineering Handbook Section 4: Hydrology, SCS-USDA, Washington, D.C.

32) Solomon, S. S., J. P. Denouvilliez, E. J. Chart, J. A. Wolley, and C. Cadou, October 1963. "The Use of a Square Grid System for Computer Estimation of Precipitation, Temperature and Runoff," Water Resources Research, American Geophysical Union, V. 4.

33) Strahler, Alan H., Dec 1, 1978. "Using Topography to Increase Forest Cover Classification Accuracy from Landsat," To be submitted to Photogrammetric Engineering.

34) Strahler Alan H., T. L. Logan, and N. A. Bryant, 1978b. "Improving Forest Cover Classification Accuracy from Landsat by Incorporating Topographic Information," Proceedings of the 12th International Symposium on Remote Sensing of the Environment, April 20-26, 1978, Manila, Philippines, Environmental Research Institute of Michigan, Ann Arbor, Michigan.

35) Strahler, A. H., 1977. "Response of Woody Species to Site Factors in Maryland, U.S.A.: Evaluation of Sampling Plans of Continuous and Binary Measurement Techniques," Vegetatio, 35: 1-19.

36) Weber, F. P., R. C. Aldrich, F. G. Sadowski, and F. J. Thompson, 1972. "Land Use Classification in the Southeastern Forest Region by Multispectral Scanning and Computerized Mapping," in Monitoring Forest Land From High Altitudes and From Space, Remote Sensing Research Work Unit, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S.D.A.

37) Wikum, D. A., and M. K. Wali, 1974. "Analysis of a North Dakota Gallery Forest: Vegetation in Relation to Topographic and Soil Gradients," Ecological Monographs, 44: 441-464.

CHAPTER 3

PART 3

Chamise Mapping

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3.1.0 BACKGROUND

The age of vegetation is a significant factor in its potential for fire hazard. This is especially true in the chaparral communities which, if undisturbed, become dense, impenetrable mixtures of live and dead fuels that can reach heights of thirty feet. Chamise chaparral, when found in continuous stands, often will be the climax community of an area due to the rockly low-nutrient soils which it inhabits and its allelopathic ability to deter the growth of other plants.

Thus, in the Los Padres National Forest, the growth of many acres of chamise chaparral continues unchecked except by natural fires and removal by hand or prescribed burning. These stands present one of the most hazardous fuel conditions in California.

LPNF fire management personnel carry out a program of prescribed burning and fire break construction to lessen the destructive potential of natural fires. The prescribed burns are planned to clear out areas of dense brush or understory accumulation. They must monitor many environmental parameters to ensure that these prescribed burns can be controlled. The location of chamise and chamise-dominant stands is important in that these represent potentially the hottest and most dangerous fuel accumulations. This is evident in that during much of the year chamise stands are sampled for moisture content, a direct measure of the parameter "green fuel moisture content" input to the National Fire Danger Rating System Fuel Model.

LPNF personnel have expressed an interest in obtaining a location map of all chamise and chamise-dominant chaparral stands in the forest. They plan to use this in fire management decisions dealing with prescribed burning and fire control resource allocation. Additionally, a map of this type would provide an areal sampling base for selecting representative green fuel moisture sampling sites.

3.2.0 METHODOLOGY

The chamise map being produced for the LPNF is derived from two data sources, Landsat multispectral images and an LPNF fire history map. It is anticipated that during the next funding year another "level" of data will be added, digital terrain information, that will provide slope , aspect and elevation input.

The LPNF fire history map was compiled from a complete record of fires occurring in the forest and just outside the forest boundary that is maintained by the Forest Service. A record is kept of each fire over 100 acres in size which includes a written description of the fire and suppression activities and a fire perimeter map on 7½ USGS quadrangles. These perimeter maps are periodically transferred to one base map for the entire forest area.

From this map a milar overlay was made that delineates areas burned during each of the ten year periods between 1930 and 1980. Thus, the map provides the following 6 classes of vegetation throughout the forest:

Class	Age	Burned
1	0-10 years	1970-1979
2	11-20 years	1960-1969
3	21-30 years	1950-1959
4	31-40 years	1940-1949
5	41-50 years	1930-1939
6	+51 years	before 1930

Using VICAR/IBIS software for creating and manipulating polygons the boundaries of these vegetation age classes were digitized and digital values were assigned each age class. Also, the LPNF boundary was digitized to overlay the age map. This map is now in a format to be overlaid digitally with a Landsat image or classified image of the area.

An undergraduate student intern with the Santa Barbara County Fire Department is presently expanding the U.S.F.S. vegetation history base map to include fires greater than 100 acres throughout the entire county of Santa Barbara. This is the first time a fire history map of the county will be available to fire suppression planners and others. This additional information will be transferred to the milar overlay and digitized. Then the two digital data sets for the forest area and the county area will be merged into a completed digital vegetation age map for all of Santa Barbara County and the southern continguous portion of the LPNF.

This digitally produced vegetation age map was produced on a film writer and is shown in Figure 3-13. The age class key is as follows:

Class		Color
1	0-10 years	black
2	11-20 years	very dark grey
3	21-30 years	dark grey
4	31-40 years	grey
5	41-50 years	light grey
6	+51 years	white

The Landsat multispectral data was used to locate chamise chaparral and chamise-dominant chaparral stands throughout the forest. The time of year is important in observing a phenological stage of chamise that distinguishes it from other types of chaparral. A classification of fuel types in Mendocino County, California was successful in delineating chamise during the post-flowering stage in the fall when the dried inflorescences are brown and stand out clearly. Thus, the Landsat overpass of 9-21-78 was chosen to classify chamise. It covers all but the northwest and southeast tips of the contiguous portion of the forest. The processing steps described below have been performed in the production of

Figure 3-13. Digital vegetation history map of the Los Padres National Forest and Santa Barbara County.

the map of the areal extent of chamise and chamise-dominant chaparral in the LPNF. Most of these steps made use of the VICAR image processing software available at UCSB.

- The Landsat CCT of 9-21-78 was submitted to VERTSLOG which converts from band-interleaved MSS format to band-sequential VICAR format and corrects geometric distortions introduced by the satellite in relation to the earth.
- A subimage of the entire Landsat scene was extracted that excludes much of the ocean in the scene.
- Four bands were selected for the chamise classification: band 5 and band 7, the red and infrared bands respectively, which are commonly used in observing vegetation; a ratio of band 4/5 which seems to give a unique description of natural vegetative regions; and the ratio of band 7/5 which has been found to normalize the effect of soil background reflectance variations.
- These four bands were submitted to the USTATS program which performed an unsupervised cluster.
- This statistical data set was in turn submitted to PDIST which calculated a Pythagorean distance matrix between clusters.
- The PDIST output was then submitted to NTSYS which produced a dendrogram of the clusters. Using this dendrogram in conjunction with a list of means for each class and band (created by MEANLIST) the number of classes was manually reduced by grouping similar classes with large variances.

- This smaller number of clusters was then submitted to EDSTATS which produces a revised statistical data set to be used in the final step of FASTCLSPR which classifies the Landsat data using the statistics provided by EDSTATS.

Once this classified image is produced, the classes will be displayed separately on a monitor and given class "labels". The class of chamise and chamise-dominant chaparral stands will be checked for accuracy against training areas previously known to be chamise and against a limited field sampling of classified sites. Inaccurate areas can be edited out or submitted again to EDSTATS for further refinement of the classification statistics used in the production of the final chamise classification.

This final classified map can then be displayed either in black and white or color on the film writer and printed at a scale desired by the U. S. Forest Service. The digital vegetation age map can then be digitally "overlaid" on the chamise map to provide a chamise age map. Work is presently continuing on improving our ability to produce line printer output of a classified map on a pixel-by-pixel basis at scales required for overlay on 7½ or 15 minute quadrangles. It is these end products that will be most useful to the Forest Service in delineating areas for prescribed burning programs or allocation of fire control resources.

3.3.0 FUTURE WORK

As mentioned previously, the third "layer" of information relevant to a chamise map that is substantially useful for the Forest Service is the digital terrain information. These digital terrain tapes can provide elevation, slope and aspect data that are significant factors in the rate of fire spread and allocation of resources. Next year's work will add this third year of information to the chamise age map.

Preliminary work with the digital terrain tapes this year indicated a major problem in including the data set at this point. The digital terrain tapes come in one degree quadrangle areas. Unfortunately, the Santa Barbara County/ LPNF area intersects four of these one degree quads. The problem is one of mosaiking these four quads together given their Lambert Conformal projections. This task is being addressed and it appears that soon an appropriate algorithm will be available to mosaic the quads together.

Once the mosaic is done the area of interest will be extracted and VICAR/ IBIS software used to create slope, aspect and elevation images. These can then either be used as channels in a refined chamise classification or as separate individual maps to be line printed and used by the Forest Service.

CHAPTER 3

PART 4

Range Management Study

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Michael Boyle

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1.0 INTRODUCTION

The University of California Geography Remote Sensing Unit (GRSU) and the Santa Barbara County of Environmental Resources (DER) are currently engaged in a cooperative project to evaluate the effects of a proposed General Plan change upon the County's rangeland economics.

The proposed change in the General Plan, which will be presented to the County Board of Supervisors, is significant in that if passed, it will set a precedent. If established, this precedent could affect the future development of large areas of Santa Barbara County which are currently zoned for extensive agriculture. In essence, it would facilitate changes in land use from agriculture to more intensive multiple uses at the expense of range carrying capacity, and the local rangeland economy.

The area of focus is Point Conception, the site of the proposed Bixby Ranch Development. The study will examine the potential impacts (if any) of this development on rangeland management operations. The analysis will compare detected effects of the proposed development upon the Point Conception area versus the County-wide availability of existing and potential rangeland.

1.1 Data Inputs

Data inputs consist of multi-date, high altitude color infrared U-2 photography, soils and geologic information, and other ancillary information.

Tasks completed to date consist of:

1. Bibliographic search
2. Selection of vegetation classification

3. Inventory and selection of appropriate high altitude color infrared photography

4. Inventory and selection of appropriate Landsat imagery October, 1978)

5. Interpretation of aerial photography

   - vegetation
   - fire/fuels
   - rangeland

6. Processing of Landsat data

   - subscene extraction
   - color composite generation (bands 4, 5, and 7)
   - unsupervised classification
   - cluster labeling (chamise, grass, water)

Output products consist of site specific (Point Conception) text, maps, and tabular summaries of: 1) range carrying capacity; 2) vegetation distribution; 3) fuel load/fire hazard rating; and 4) erosion potential for selected areas on site. At the County level the output products consist of County-wide inventories of: 1) existing rangeland; 2) chamise brushland (amenable to conversion); and 3) existing surface water distribution.

The important management decision which may occur as a result of remote sensing input is a site specific range conversion schedule as a possible mitigation measure for range areas negatively impacted by development. The actual management decision lies with the Santa Barbara County Board of Supervisors who may direct the Department of Environmental Resources to plan and implement a county-wide range. conversion program based upon this project's results. Additionally, an evaluation by DER will be made of the utility of Landsat technology and high altitude imagery as it relates to County-level information in the land/development process.

1.2 Results

The products of this study are in the following pages. The "Results" section includes the maps, descriptions of procedures, and summaries.

1.3 Future Work

Because of the strong support provided by Santa Barbara County through the contribution of staff time, hiring of individuals dedicated to the project, and the enthusiastic anticipation of future efforts, more emphasis will be placed upon the Santa Barbara County portion of subsequent work to be done under these grant funds.

2.0 VEGETATION

The vegetation map for Bixby Ranch (see Figure 3-14) was compiled with the use of the following inputs:

1. USGS 7½' quadrangle 1:24,000 scale topographic hydrologic and roads data.

2. Color infrared imagery 1:130,000 scale flown in April 1971.

3. Color infrared imagery 1:65,000 scale flown in April 1971.

4. Panchromatic black and white imagery 1:20,000 scale flown in 1967.

5. Color infrared imagery 1:65,000 scale flown in March 1978.

6. Selected field observation.

2.1 Procedure

Compilation of the Bixby Ranch Vegetation Map was accomplished by manual aerial photo interpretation with the aid of a Bausch and Lomb Stereo Zoom Transfer Scope (SZTS) model ZT4-H9 and a Bausch and Lomb Monocular Zoom Transfer Scope (MZTS) model ZT4-H9.

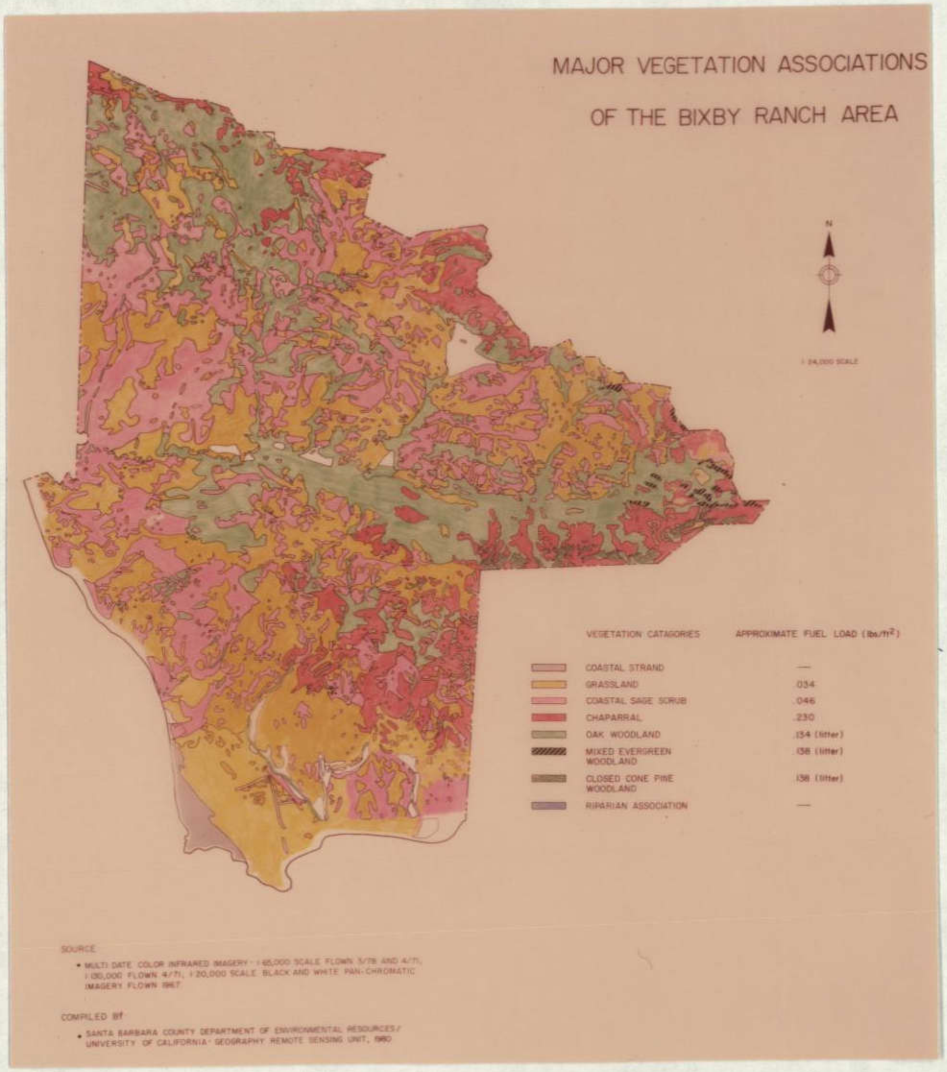

Figure 3-14. Vegetation of the Point Conception area (original scale = 1:24,000).

MZTS allows the photo interpreter to optically overlay an aerial image and register it to a map of any scale, in this case 1:24,000 scale.

Utilizing the SZTS, the interpreter can overlay a stereo image onto a map. The stereo image has the advantage of projecting a three dimensional image onto maps, which enhances the interpreter's ability to identify and map vegetation associations of interest.

2.2 Analysis

Woodland associations/communities were mapped with the use of the SZTS from 1:20,000 scale black and white Panchromatic prints. The ability to conduct photo interpretation with a three-dimensional perspective, overlayed with a 7½' quadrangle topographic map, yields significant spatial integrity in the plotting of woodland polygons.

All other vegetation class polygons were plotted using the MZTS and March 1978 color infrared imagery, 1:65,000 scale. Refinement of the classification was accomplished from interpretation with the use of a stereoscope, and multiscale (1:65,000 and 1:120,000) color infrared imagery flown in April 1971.

A greater degree of nominal refinement in the vegetation classification can be achieved with additional field surveys.

2.3 Associations

2.3.1 Coastal Strand

The Coastal Strand associations occur mainly at Point Conception and Jalama Beach. Neither of these two sites sustain a very well developed community, although the Point Conception areas are more extensive in areal distribution.

At Point Conception, the Coastal Strand occurs on an uplifted marine terrace. Consequently, the habitat is not easily replenished of soil lost through erosion, and is thus sensitive to human disruption.

The dominant species of the Coastal Strand include, but are not limited to: Silver Beech Weed (<u>Franseria chamissonis</u>), Seep Weed (<u>Sueda california</u>), Beach Primrose (<u>Camissonia chenianthifola</u>), and Hottentot Fig (<u>Mesebranthansum edule</u>).

The Coastal Strand Community comprises approximately 48 acres or 0.02 percent of the Bixby Ranch area.

The climate in the area occupied by the coastal strand plant community is relatively moderate. Average rainfall is approximately 12-15 inches in Southern California. The humidity is very high year-round and fogs are present during both summer and winter months. The growing season is very long and because of the moderating effect of the adjacent ocean, diurnal, as well as seasonal temperature fluctuations are relatively small. An average summer high is about 70°R, while winter lows rarely drop below 50°F.

The first terrestrial plant community encountered above the high tide line is the Coastal Strand. It is characterized by a relatively sparse vegetation on sand dunes and beaches.

Despite moderate climatic conditions, the Coastal Strand environment is relatively harsh. The community is subjected to strong salt-laden winds and occasional high tides which concentrates sea salts on the plants and soil. Besides being salty, this sandy substrate is often very unstable and is blown about by the wind, making it difficult for plants to become established. Beach soils are loose and sandy, excessively drained and generally low in plant nutrients. During summer months, surface temperatures on the sand may become hot, frequently exceeding 90°F. This increases the evapotranspiration potential of this vegetation and tends to dessicate and damage less hardy plant species. Coastal Strand plant species are generally well adapted to these conditions. Plants found here are frequently succulent and are able to utilize water whose salt content would dehydrate most plants. Because of the fact that wind is constantly moving sand around, plants in this community are generally prostrate and have creeping stems. This adaptive feature allow plants to trap their own soil and creates stabilized sand dunes covered by this vegetation. In some species, these stems may produce roots at the nodes and eventually form a large colony derived from one individual plant. Finally, many Coastal Strand plants have greyish foliage that serves to reflect intense daytime temperatures to which they are subjected.

2.3.2 <u>Grasslands</u>

Grasslands of the Bixby Ranch range from pure grass associations, primar transitional grasslands to secondary transitional grasslands. The primary transitional grasslands consist of introduced grasses codominant with Field Mustard (<u>Brassica</u> sp.) and other herbaceous plants of similar physiological character. Secondary transitional grasslands consist of grass species intergraded with emergent Coast Sage Scrub species such as Californica sage brush, Sawtooth Golden Bush (<u>Haplopappus</u> sp.), Coyote Bush (<u>Baccharis pilularis</u>), and Lupine (<u>Lupinus</u> sp.).

Together all three grasslands comprise 7,128 acres or 29.7% of land cover at Bixby Ranch.

Mediterranean climate with its cool moist winters and dry summers has favored the development of annual and perennial grassland plant communities throughout Southern California. Typically the best developed grasslands exist between sea level and about 4,000 feet, where yearly rainfall averages between 15 and 30 inches and temperatures are moderate. Higher mountains and woodlands receiving up to 40 inches of precipitation are more commonly associated with perennial grasses.

Growth characteristics of grasses are extremely important factors in the distribution and adaptation of these floras to existing climatic conditions. For this reason, grass species are characterized as either being perennial or annual. Under favorable conditions, perennial grasses emerge from dormanc or revive by active vegetative growth from the base of the existing plant stock. Annual grasses, on the other hand, complete their entire growth and reproductive cycle within one season's or year's time, and die at the end of this period. Under normal environmental conditions, they are aggressive, quick growing and produce tremendous quantities of seed. In comparison, perennial grasses often do not produce viable seed until their second growing season and often cannot compete well against annuals on semi-arid to arid soils.[1]

Over half of the grass species growing in California occur at lower elevations along the coast. Since native and naturalized grasslands intergrade and compete with vegetation occupying brushlands and wooded slopes, they are best developed on open, sparsely vegetated hillsides and valleys. Expansion of grasses into other closely associated plant habitat occurs as a result of cattle grazing, conversion of brushlands to range, fuel modificating projects and brush fires. Generally, these are characterized by non-native, annual species that compose a transitional phase of plant succession. If disturbance does not continue, these grasslands eventually are replaced by naturally occurring climax vegetation.[2]

Soil is an important factor in the distribution of grasses. The best grassland soils are dark in color, medium to heavy in texture, contain a fair amount of organic material and have good water-holding capacities. Grasses tend to grow on much shallower soils than trees and frequently these communities occupy residual soils where the depth to bedrock is only a few inches. Poorly drained soils which are unsuited for most agricultural purposes have also become favorable grassland habitats since their introduction to these localities. In areas where these soils have developed from marine sediments such as shale, good water-holding characteristics combined with high levels of carbonates necessary for plant growth, have established grassland floras throughout the gently rolling hills and valleys of the coast and interior ranges.

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[1]Exceptions to this rule occur where introduced perennials from North Africa and Australia have become established in disturbed sites. These grasses are well adapted to arid environments even to the exclusion of certain xermorph'c shrubs.

[2]Native species depend upon a combination of suitable climatic conditions, soil type and preferred habitat for their development. Therefore, naturalize species frequently are more easily established in disturbed sites due to the fact that they are seldomly limited by all of these factors.

2.3.3 Coastal Sage Scrub

The Coastal Sage Scrub Associations at Bixby Ranch occur in a variety of successional stages and floristic compositions. Some associations consist of dense, pure stands of Purple Sage (Salvia leucophylla) and California Sage Brush (Artemisa californica). Other associations occur as "mixed Coastal Sage" which consist of intergrades and contiguous associations of California Sage Brush, Rye Grass, Bush Monkey Flower, Coyote Bush, Bush Sunflower, Lupines and other species as well. In total, Coastal Sage Associations comprise approximately 25.9% or 6,216 acres of Bixby Ranch land cover.

Due to the relatively wide distribution of this plant community, climatic conditions tend to be more variable as the distance from the coast increases. For this reason, Coastal Sage Scrub occurs in two rather sharply contrasting climatic environments.

One is maritime and is characterized by low foothills and valleys immediately adjacent to the ocean and extending inland for several miles. Here, diurnal and seasonal temperatures are moderated by the presence of the nearby ocean. The average annual rainfall is 15-25 inches. Humidity tends to be higher and low clouds are relatively common. Average air temperatures in summer average between 75 to 85°F and winter lows are around 55°F. The other is a much drier, warmer environment as you progress inland to more insular locations. In these areas both diurnal and seasonal temperatures tend to be more extreme.

The Coastal Sage Scrub Plant Community is characterized by a predominance of sub-shrubs, one to five feet in height with semi-woody stems growing from a woody base. Because of the flexibility of both branch and leaf, this plant community has also been called "soft chaparral." Special adaptations to such environmental factors as winter rainfall and summer aridity are expressed by many species that occur here. Summer dormancy, long taproots, resinous plant parts and reduced leaf size are just a few of the plant adaptations that are commonly utilized by these plants to conserve water during dry summer months.

Of the two Coastal Sage Scrub environments that have been described, the coastal or Maritime Zone tends to be much more densely vegetated. In contrast to this distribution, the interior form is generally more sparse and occupies rather thin rocky soils of steeper slopes. Like its seaward counterpart, it is usually found below 3000 feet and tends to intergrade with Foothill Grassland Chaparral species. Because a continuum exists between these extremes, corresponding variations in distribution pattern can be expected to occur.

2.3.4 Chaparral

Chaparral occurs in a variety of forms on Bixby Ranch, and together, these forms of chaparral comprise approximately 16.5% or 3,912 acres of the Bixby Ranch land cover.

Dominant species of the chaparral include, but are not limited to: Chamise (Adenostoma fasciculatum), Coffee Berry (Rhamnus californica), Scrub Oak (Quercus dumosa), and Manzanita (Arctosaphytos sp.). Chaparral is subject to occur in large dense stands of single species, in co-dominance with a few species or in mixed associations. In certain instances, this plant community intergrades with the Foothill and Closed Cone Pine Woodlands.

Chaparral consists of broad-leaved sclerophyll shrubs, 5-10 feet tall, forming dense, often impenetrable vegetation. Species of this community are typically deep rooted. The community usually has no understory vegetation. Growth may occur throughout the year, but is highest in the spring and much reduced during the late summer-fall dry season. Many species of the chaparral have adapted to repeated fires and respond by crown sprouting.

A dense cover of annual herbs may appear during the first growing season after a fire, followed by subsequent years of perennial herbs, short-lived shrubs and reestablishment of dominance by the original shrub species.

Found on dry slopes and ridges in the Coast and Transverse ranges on rocky gravelly or fairly heavy soils. Average rainfall ranges from 14-25 inches with hot dry summers and cool, but not cold, winters.

2.3.5 Foothill Woodlands

Foothill Woodlands of Bixby Ranch are generally well developed, hardy, and occur in varying densities. Oak Associates on the interior portions of the ranch have a chaparral understory, while the same Oak species under the influence of the maritime environment, and culling management practices, have a grassland understory.

The Foothill Woodland species consist of Coast Live Oak (Quercus agrifolia), Scrub Oak (Quercus dumosa), and probably other Quercus species as well.

The Foothill Woodland occurs as part of the Mixed Evergreen and Closed Cone Pine vegetation complexes as well.

Foothill Woodlands comprise approximately 4,482 acres or 18.6% of the Bixby Ranch land cover.

Because Foothill Woodland Plant Communities have wide elevational distribution patterns within California (300-5000 feet), they frequently occupy favorable plant habitats within highly variable climatic ranges. Depending upon the distance from the ocean and the altitude at which these communities occur, seasonal temperatures and rainfall will vary. Rainfall in coastal hills and valleys averages from 15-25 inches annually. This rainfall is typically very heavy, occurring over relatively short periods of time and rapidly runs off these areas. Average summer highs vary from 80°F in coastal areas. Winter lows will range from 40°F near the coast. Humidity levels also tend to be slightly higher than surrounding areas, especially on more densely vegetated north-facing slopes. Here, reduced light penetration, lower temperatures and increased humidity create a "microclimate" that supports Mesophytic, shade-tolerant, understory vegetation.

The Foothill Woodland Plant Community extends inland discontinuously from coastal hills and valleys to broad interior basins and mountainous slopes. It is characterized by two forms that range from widely scattered oak and grassland associations to densely spaced oak and shrub dominant plant communities. In drier locations, characterized by rollings hills and valleys with heavy clay soil, this community is expressed as an Oak Savannah. Here, oaks tend to be widely spaced and their form is spreading. Ground cover almost exclusively consists of herbaceous plants, with the most dominant species being grasses. In upland areas, characterized by steeper northfacing slopes and hillsides, dense stands of oaks intergrade with other tree and shrub species, to form the dominant vegetation in these woodlands. In some cases, crowns of these trees intertwine to form a "canopy effect" which greatly reduces light penetration. Here, tree forms are typically narrower with longer trunks and branches bending upward toward the light. Understory vegetation in these areas is shade tolerant and frequently composed of low shrubs, herbs, ferns, fungi and a few long stemmed grass species. Soil tends to be leaf littered, moderately fertile and has higher moisture content.

2.3.6 Riparian

Riparian associations at Bixby Ranch occur mainly in Jalama Creek, its tributaries, and in stream beds west of the Cojo Ranch building complex. As Riparian associations comprise a minor portion of the total vegetation/land cover for the ranch, only the larger communities were identified in this study. Refinement of these vegetation classes is needed for a complete asses ment of biological resources on the ranch.

Riparian associations of Bixby Ranch consist of dense willow thickets (Salix Sp.), and riparian woodland. The riparian woodlands are dominated by Red Alder (Alnus rombifolia), Fremont Cottonwood (Populus fremonti), Southern California Walnut (Juglans californica), and willow species.

The total number of acres of both riparian associations together is approximately 126 or 0.005 of the total Bixby Ranch land cover.

Riparian associations often occupy widely scattered drainage systems, and tend to be subjected to a variety of climatic conditions. Depending upon distance from the ocean and the altitude at which they occur, climatic influences are generally similar to those experienced by other plant communities through which they pass. However, "micro-climates" may exist with riparian environments as a result of topographic location, prevailing wind conditions and transportation of water vapor by broad-leaved plant species.[1] Winter lows tend to be lower than surrounding areas where perennial water or larger trees are present. Prevailing sea and land breezes combined with increased humidity levels and reduced light penetration moderate these temperatures by as much as 15-20°F. Rainfall in riparian plant communities is similar to surrounding areas; however, runoff from higher ground accumulates along these drainage basins. This increased water velocity during winter storms

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[1]It should be noted that in Southern California, riparian plant communities are highly variable in their overall composition and development. For this reason, moderating effects on temperature and the creation of "micro-climates' depend largely upon: availability of water, diversity of vegetative cover and maturity of the plant community.

removes vegetation that has become established within the stream channel when water levels were lower.

Along intermittent streams that receive only limited amounts of runoff from smaller watersheds, these communities tend to be dominated by shrubs and a few trees that are able to tap deep subsurface water sources.

Although riparian species are generally characterized as deciduous, broad-leaved, terrestrial plants that rely on wind for pollination and distribution, many aquatic plants that are present in other freshwater habitats may be found here as well. During summer months when water velocities slow down and temperatures increase, algal growth correspondingly increases as does herbaceous aquatic vegetation lining these waterways.

The significance of this plant community in terms of biological productivity is directly related to diversity of its component plant species and the habitat they provide wildlife.

2.3.7 Closed Cone Pine Woodland

Closed Cone Pine associations occur as emergent relict vegetation in chaparral at the extreme western end of the Santa Ynez Mountains. It is comprised of Bishop Pine and intergrades with oaks. It is possible that Knotocone Pine (*Pinus attenuata*) could occur in the CCP community.

It appears that, besides the maritime influence on Closed Cone Pine habitat, that community distribution is tied to local geologic amenities.

Closed Cone Pine communities are relatively incommon in both the state and the county.

2.3.8 Mixed Evergreen Woodland

Mixed Evergreen Woodland occurs at the eastern part of Bixby Ranch in the upland areas immediately north of the Santa Ynez Mountains. Dominant plants of this plant community include Madrone (*Arbutus menziesii*), California Bay (*Umbellularia californica*), Tan Oak (*Lithocarpus densiflora*), and Big Leaf Maple (*Acer Macriphyllum*).

This community is a relict association in favorable north-facing slopes.

3.0 FUEL LOAD/FIRE HAZARD

The area of the Bixby Ranch Management boundary Station 51 - Fire Management Area 4. These fire related ratings are meant to assist fire fighting agencies in determining the potential behavior of any particular fire based upon the generalized fuel characteristics of the area.

A detailed vegetation map was generated for this study from several types of aerial photography. The vegetation categories were then related to several fuel models developed by the U. S. Forest Service. The fuel models most closely approximating the vegetation within our study area were the stylized fuel models included in "Estimating Wildfire Behavior and Effects" by Frank Albini, USDA, Forest Service, General Technical Report INT-30. Average fuel loads in pounds per square foot were given for each fuel model and the user is urged to sample for discrepancies between the fuel situation in the field and the stylized fuel models used here in order to more accurately predict the reaction intensity (heat release) and rate of spread.

In addition, the detailed vegetation map was generalized into major fire hazard categories of:

1. grass = moderate hazard (direct attack)
2. chaparral = high hazard (direct attack under favorable conditions, indirect attack under severe conditions)
3. oak with brush understory = critical hazard (indirect attack unless under the most favorable conditions)

Included on the Fire Hazard Rating map (see Figure 3-15) are major activity areas considered to be potential sources of fire ignition, e.g., public roads, Jalama Beach Park, and the railroad. Also included on the map are private roads throughout the ranch, for access by fire fighting equipment.

These fuels-related maps are intended for use by fire suppression and fire prevention personnel. Any development planning activities, for example, related to fire insurance estimation, would require refinement of the maps by field data collection.

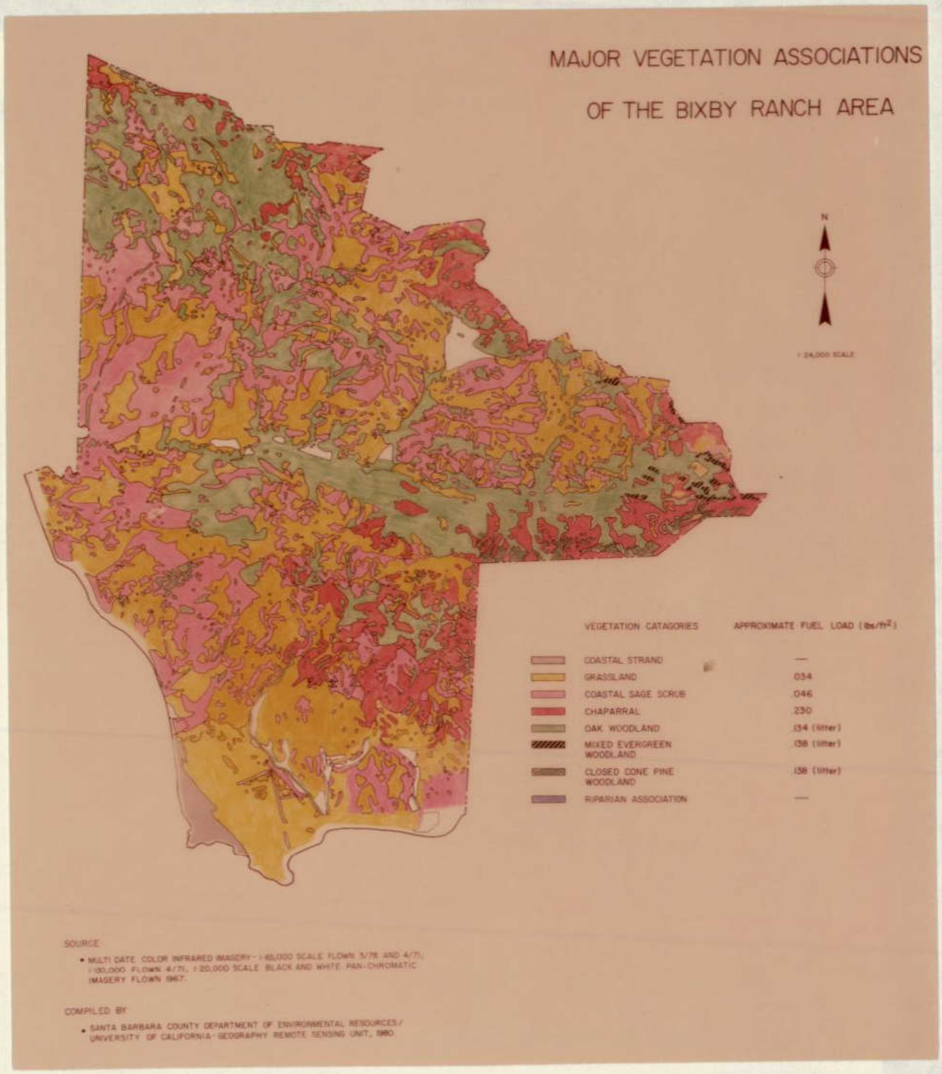

Figure 3-15A. Fuel Load map for Point Conception area (original scale = 1:24,000).

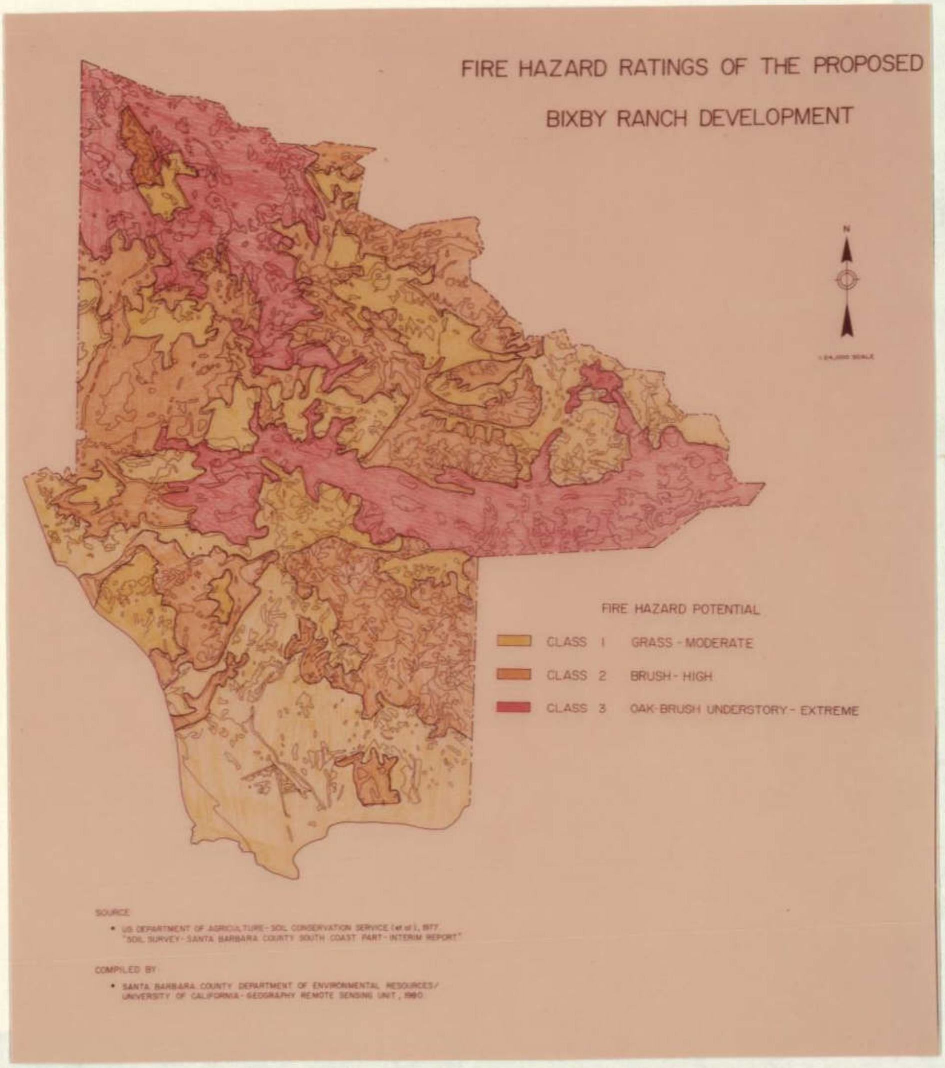

Figure 3-15B. Fire Hazard map for Point Conception area (original scale = 1:24,000).

4.0 SOIL EROSION POTENTIAL

The potential for soil erosion is a combination of the rate of water runoff and the susceptibility of the soil to erosion by water. Soil properties that influence runoff effect the minimum rate of infiltration into the bare soil after prolonged wetting and are influenced by the depth to a water table, water intake rate, permeability, and depth to layers of slowly or very slowly permeable soil. Soil properties which influence the susceptibility of soil particles to detachment and transport by rainfall include: soil texture, percent of sand greater than 0.1 mm, soil organic matter content, soil structure (type, grade), soil permeability, clay mineralogy, and coarse fragments.

The USDA, Soil Conservation Service, Soil Survey for Santa Barbara County (August 1977) rates water runoff from slow to very rapid, and soil erosion hazard from slight to very high. Using this data as a base, the potential for soil erosion was categorized according to the following scheme:

1. The water runoff for each soil was given a rating of 1 to 4 (1=slow, 2=medium, 3=rapid, 4=very rapid);
2. the water erosion hazard for each soil was given a rating of 1 to 4 (1=slight, 2=moderate, 3=high, 4=very high);
3. the two numbers were then ADDED to obtain a range of ratings for soil erosion potential from 2 to 8 (7 categories).

An optimum number of categories for erosion potential was considered to be 4 in order to be consistent with the source material. Thus, the 7 ratings were grouped into 4 categories (2=low, 3-4=medium, 5-6=high, 7-8=very high). In addition, the Soil Survey indicated two soils which were highly susceptible and moderately susceptible to erosion from wind.

The final classification is as follows (see Figure 3-16):

class 1 = low soil erosion potential from water
class 2 = medium soil erosion potential from water
class 3 = high soil erosion potential from water
class 4 = very high soil erosion potential from water
class 5 = moderately susceptible to erosion from wind
class 6 = highly susceptible to erosion from wind

A comparison between soil erosion potential ratings obtained through this method and the ratings supplied by SWA Group-Land Planners may be seen in Table 3-1, Soil Erosion Potential Ratings.

5.0 RANGE CARRYING CAPACITY

The purpose of the Existing, and Potential Rangeland Yield maps (see Figure 3-17) is to help provide the Department of Environmental Resources (DER) with sufficient base information to assess the potential decrease in rangeland carrying capacity resulting from loss of range associated with the proposed Bixby Ranch Company Development.

The techniques used to derive rangeland carrying capacity estimates are but two approaches to the problem and are not designed to be exhaustive of the topic. Instead, the maps and supporting text are designed to provide DER with base information: to assess the current state of rangeland conditions at Bixby Ranch; to compare with information submitted by the developer; and to assist in identifying appropriate potential range conversion sites to mitigate, to the extent possible, the adverse impacts of any decrease in rangeland yield from converting existing rangeland to residential use.

5.1 Potential Rangeland and Yield

Figures are derived by compiling SCS soils series polygons onto

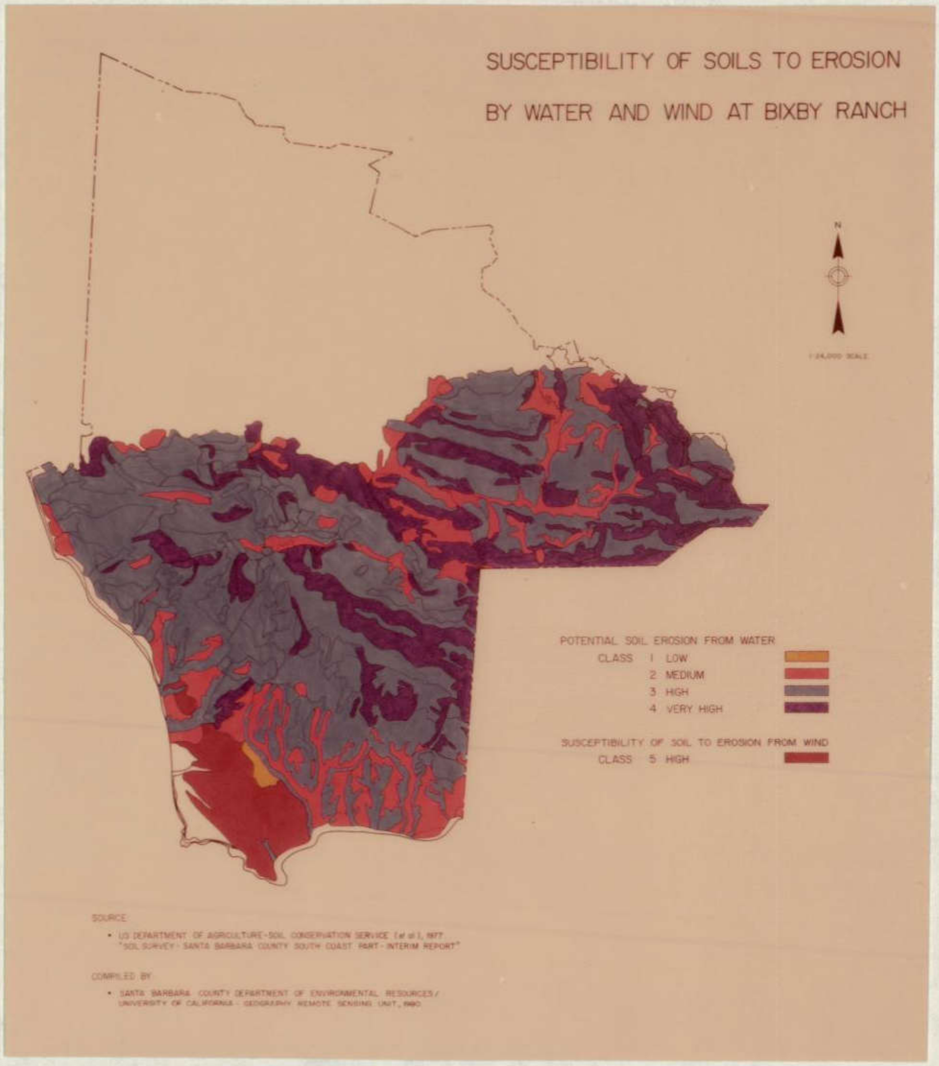

Figure 3-16. Map of Soil Erosion Potential for Point Conception area (original scale = 1:24,000).

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Table 3-1. SOIL EROSION POTENTIAL RATINGS

SOIL NAME*	MAP SYMBOLS	RUNOFF* (rating) +		EROSION HAZARD* (rating) =		EROSION POTENTIAL		SWA GROUP RATING**
Agueda	AaC - AGC	Medium	(2)	Moderate	(2)	Medium	(4)	
Argixerolls	AE - LS	Med.-rapid	(2.5)	High	(3)	High	(5.5)	
Ballard	BaC - BBC	Medium	(2)	Moderate	(2)	Medium	(4)	
Beaches	BE -CO	------		-------		------		
Botella	BgC - BOC	Medium	(2)	Moderate	(2)	Medium	(4)	
	BhC - BGC	Medium	(2)	Moderate	(2)	Medium	(4)	
Camarillo	Ca -CM	Slow	(1)	Moderate	(2)	Medium	(3)	
Capitan	CcF - CPF2	Rapid	(3)	High	(3)	High	(6)	High erosion
	CdG - CPG	V. Rapid	(4)	V. High	(4)	V. High	(8)	Very high erosion
Concepcion	CeB - NRB	Slow-med.	(1.5)	Slight-to-Mod.	(1.5)	Medium	(3)	
	CeB - NRB	Highly susceptible to wind erosion						High susceptible to wind erosion
	CgC2 - WAC2	Slow-med.	(1.5)	Slight-to-Mod.	(1.5)	Medium	(3)	
	CgD2 - WAD2	Rapid	(3)	High	(3)	High	(6)	
	CgE2 - WAE2	Rapid	(3)	V. High	(4)	V. High	(7)	
Diablo	DaC - DIC	Medium	(2)	Slight	(1)	Medium	(3)	
	DaD - DID	Medium	(2)	Moderate	(2)	Medium	(4)	
	DaE2 - DIE2	Rapid	(3)	High	(3)	High	(6)	
	DaF2 - DIF2	Rapid	(3)	High	(3)	High	(6)	High erosion
Dune Escorpments	DU - DU	------		------		------		
Gaviota	GaE - GVE	Medium	(2)	Moderate	(2)	Medium	(4)	
	GaG - GVG	Rapid	(3)	V. High	(4)	V. High	(7)	Very high erosion
	GbG - GRH	V. Rapid	(4)	V. High	(4)	V. High	(8)	

Table 3-1 (continued)

SOIL NAME*	MAP SYMBOLS	RUNOFF* (rating)		+	EROSION HAZARD* (rating)		=	EROSION POTENTIAL		SWA GROUP RATING**
Lopez	LaG - LOG	V. Rapid	(4)		V. High	(4)		V. High	(8)	
	LeE2 - LAE2	Med.-rapid	(2.5)		High	(3)		High	(5.5)	
	LeF2 - LAF2	Rapid	(3)		High	(3)		High	(6)	High erosion
Los Osos	LgE2 - LLE2	Medium	(2)		Moderate	(2)		Medium	(4)	
	LgF2 - LLF2	Rapid	(3)		High	(3)		High	(6)	High erosion
	LhG - LMG	V. Rapid	(4)		V. High	(4)		V. High	(8)	Very high erosion
Maymen	MaG - MAG	V. Rapid	(4)		V. High	(4)		V. High	(8)	
	MbH - MRG	V. Rapid	(4)		V. High	(4)		V. High	(8)	
Milpitas	MeD2 - MID2	Rapid	(3)		High	(3)		High	(6)	
	MeE2 - MIE2	V. Rapid	(4)		V. High	(4)		V. High	(8)	Very high erosion
Nacimiento	NaF2 - NAF2	Rapid	(3)		High	(3)		High	(6)	Highly susceptible to slippage
	NbG - NLG	Rapid	(3)		V. High	(4)		V. High	(7)	
Rock Outcrop	Rb - RMH	V. Rapid	(4)		V. High	(4)		V. High	(8)	
San Andreas	SaE2 - STE2	Medium	(2)		Moderate	(2)		Medium	(4)	
	SaF2 - StF2	V. Rapid	(4)		V. High	(4)		V. High	(8)	Very high erosion
Santa Lucia	ScD2 - SAD2	Medium	(2)		Moderate	(2)		Medium	(4)	
	ScE2 - SAE2	Rapid	(3)		High	(3)		High	(6)	
	ScF2 - SAF2	Rapid	(3)		High	(3)		High	(6)	High erosion
	ScG - SAG	V. Rapid	(4)		V. High	(4)		V. High	(8)	Very high erosion
Zaca	ZaE2 - ZAE2	Rapid	(3)		High	(3)		High	(6)	
	ZaF2 - ZAF2	Rapid	(3)		High	(3)		High	(6)	

*Source: Soil survey, Santa Barbara County, California, South Coastal Part, Interim Report, August, 1977, U.S.D.A. Soil Conservation Service, Forest Service, U.C. Agricultural Experiment Station, Santa Barbara Resource Conservation District, Lompoc Resource Conservation District.

**Source: Environmental Evaluation for the Bixby Ranch Company Cajo and Jalama Ranches, Santa Barbara, California; The SWA Group-Land Planners, April, 1978.

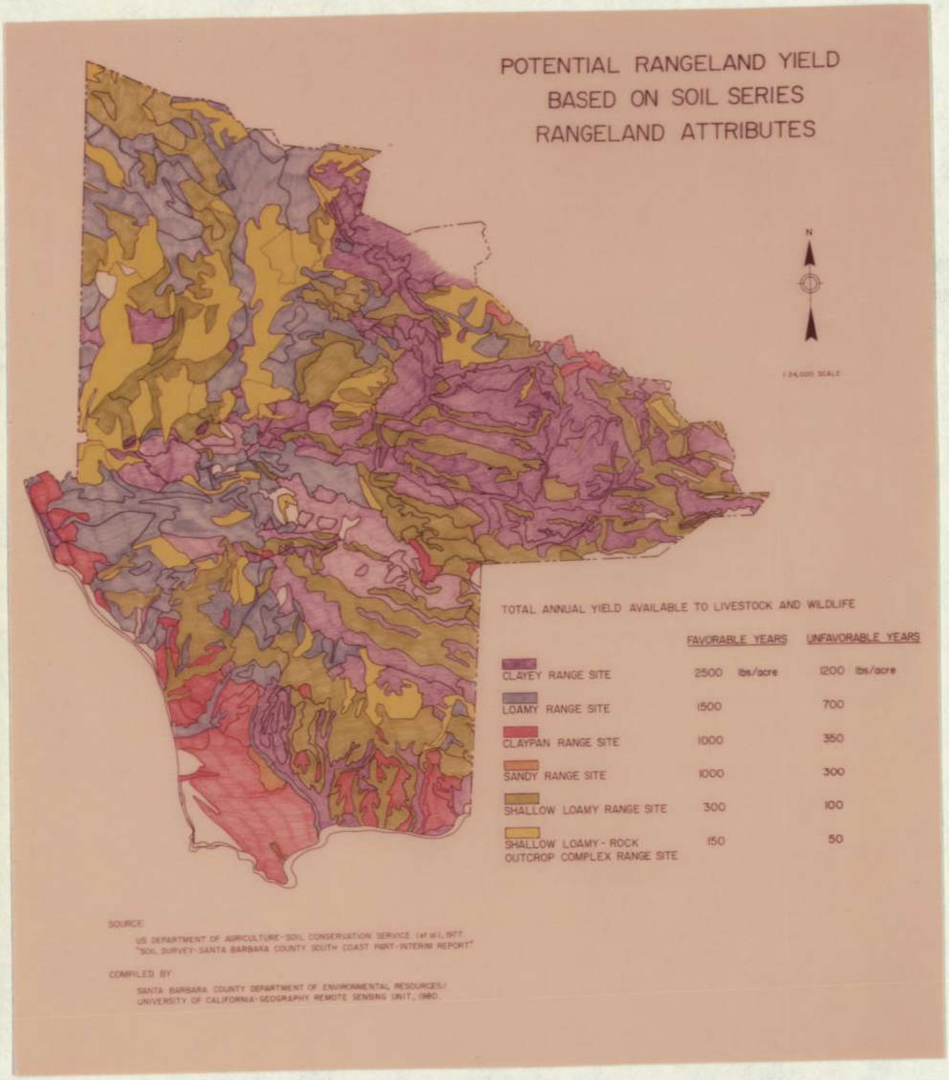

Figure 3-17A. Potential Rangeland Yield map for the Point Conception area (original scale = 1:24,000).

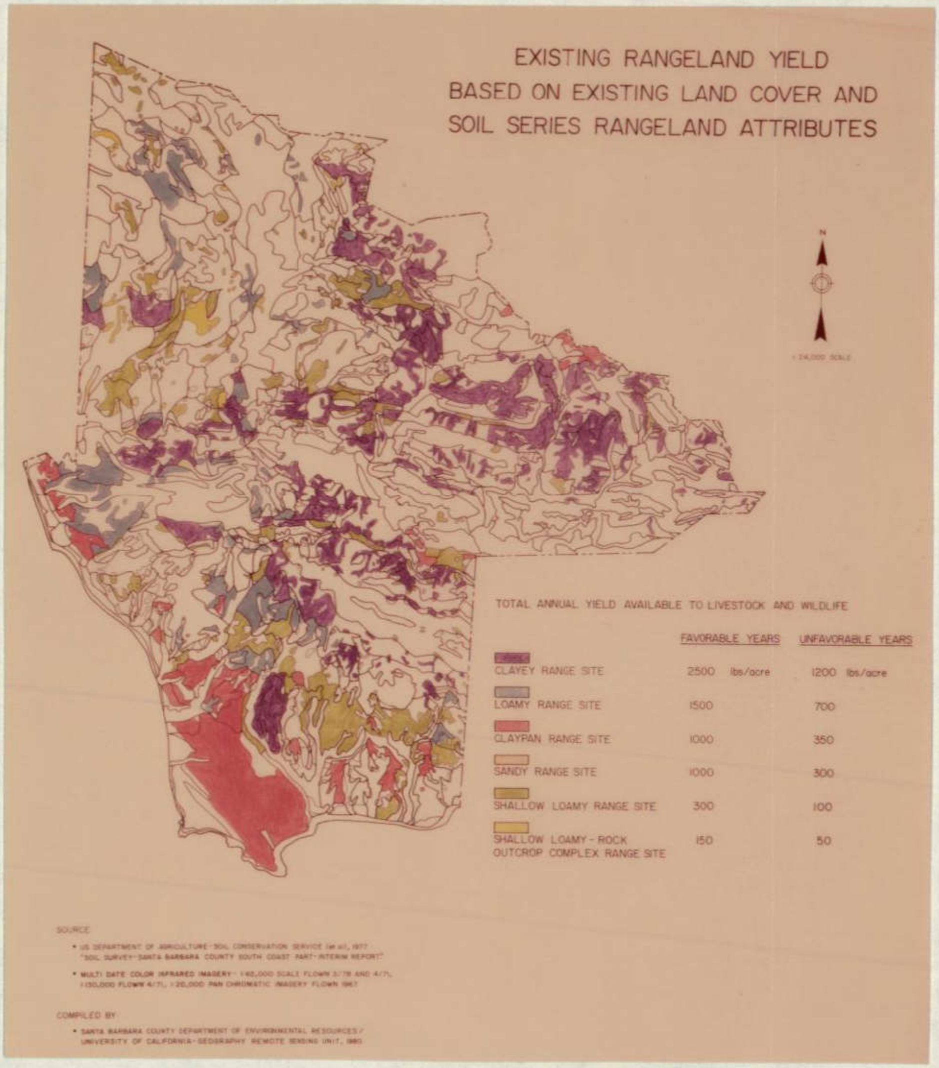

Figure 3-17B. Existing Rangeland Yield map for the Point Conception area (original scale = 1:24,000).

a USGS 1:24,000 scale mylar and measuring soils which share the same Potential Range Site Description. The Potential Range Site Description (potential yield estimates) are used to assess the number of potential Animal Unit Months (AUM) each soil series can theoretically support over one year's time.

Each soil series has, as one of many attributes, a measurement of potential annual forage available to livestock and wildlife during favorable and unfavorable years. Potential forage yield estimates are converted to AUM's by dividing the number of pounds of forage an animal unit (of 1000 lbs) requires per month, into the min and max potential annual forage yield estimates associated with each soil series. These calculations result in one estimate of the AUM's each Potential Range Site could support for one year -- other things being equal. The AUM's per range site were then aggregated into (fenced) pasture units.

5.2 Existing Rangeland Yield

Figures are based on the potential forage yield estimates (SCS soil-based method) described above but modified by present land cover. In the case of a potentially productive range soil which presently supports a stand of chaparral, the potential carrying capacity estimates are modified to exclude yield estimates for all areas not presently supporting pure and transitional grasslands. Once these new polygons are measured, the resulting yield figures (ton/acre/year) are divided by the amount of forage used by one "animal unit" for one month (33 lbs per day air-dry weight x 30 days = 990 lbs per month). The procedure results in an estimate of the average minimum and maximum number of potential AUM's which a given pasture unit can support for one year (see Table 3-2). The estimates are only one measure of existing range carrying capacity and should be refined with the input of collateral information.

In order to refine range carrying capacity (RCC) estimates other factors should be taken into consideration, such as observed/actual ranch yield (records) over the past 10-15 years; criteria for managing ranch operations (i.e., number, type, and age of cattle -- managed over time); more specifically the criteria for managing each pasture unit. Other significant factors include competition with wildlife, brushland encroachment, soil moisture holding capacity, availability of and distance to water, fertility of the soil, etc. All of these factors affect cattle crop yield to some extent, and resolving some or all of these factors will aid in refining the base data generated in this study. Once collateral information is taken into consideration, the study should be definitive of rangeland practices and potential rangeland carrying capacity at Bixby Ranch.

Recent field observations at Bixby Ranch indicate that there has been a significant amount of range conversion of Coastal Sage Scrub to grasslands through prescribed burning practices. It is likely that the information generated in this study could provide input into future prescribed burning practices (mitigation) to offset yield losses due to the decrease in existing rangeland conversion to residential use.

5.3 Landsat

An unsupervised classification was performed using Landsat data from October, 1978. The image was partitioned into spectral categories that were sufficiently similar to be considered "types." This spectral

Table 3-2. RANGE CARRYING CAPACITIES PER PASTURE UNIT*

JALAMA			
Major Pasture Units	Acreage	Potential Carrying Capacity (Ave.)	Existing Carrying Capacity (Ave.)
1	3,186	982.2 - 2108.6 (1552.9)	301.3 - 646.8 (476.6)
2	745	146.0 - 367.9 (256.0)	28.2 - 72.5 (50.4)
3	1,423	610.0 - 1355.0 (982.0)	29.3 - 63.9 (46.6)
4	108	43.9 - 107.0 (75.5)	30.9 - 67.3 (49.1)
5	157	57.2 - 144.5 (100.9)	10.2 - 21.0 (17.1)
6	935	502.0 - 1065.0 (783.5)	161.7 - 368.0 (264.9)
7	733	259.2 - 609.8 (434.5)	78.6 - 188.2 (133.4)
8	188	116.8 - 264.7 (190.8)	39.2 - 45.6 (42.4)
9	623	412.0 - 932.0 (672.0)	272.4 - 609.1 (440.0)
10	438	146.0 - 361.0 (253.5)	14.5 - 35.3 (24.9)
11	504	314.5 - 697.5 (506.0)	122.5 - 271.0 (196.8)
12	526	310.0 - 700.0 (505.0)	90.0 - 226.0 (105.0)
13	562	301.1 - 705.0 (503.1)	56.6 - 177.5 (117.1)
14	1,219	728.3 - 1648.0 (1188.0)	270.7 - 605.0 (437.9)
15	122	108.0 - 241.0 (174.0)	68.2 - 151.0 (109.6)
16	115	72.7 - 168.0 (120.4)	24.7 - 54.4 (39.6)
17	2,492		
Minor Pasture Units			
A	28	18.3 - 40.7 (29.5)	14.8 - 32.6 (23.7)
B	70	49.5 - 110.0 (79.8)	24.4 - 54.1 (39.3)

*in AUM's (animal-unit months)

~~398~~ 391

Table 3-2 (continued)

COJO			
Major Pasture Units	Acreage	Potential Carrying Capacity (Ave).	Existing Carrying Capacity (Ave.)
1	1,507	838.0 - 1869.0 (1349.0)	342.2 - 767.0 (554.0)
2	1,412	539.8 - 1294.2 (916.0)	214.2 - 577.9 (396.0)
3	1,230	722.5 - 1632.0 (1177.0)	340.9 - 753.0 (547.0)
4	1,537	720.0 - 1611.0 (1165.0)	136.7 - 307.8 (222.3)
5	230	186.5 - 414.0 (300.0)	129.1 - 285.0 (207.0)
6	178	74.5 - 201.0 (137.8)	53.1 - 151.9 (102.5)
7	268	79.6 - 235.8 (157.7)	47.3 - 135.5 (91.3)
8	242	85.4 - 244.1 (164.8)	74.7 - 213.0 (143.9)
9	105	37.3 - 108.0 (72.3)	35.6 - 104.0 (69.8)
10	157	104.2 - 260.0 (182.1)	41.4 - 107.2 (74.3)
11	613	288.4 - 821.0 (554.7)	32.8 - 94.3 (63.5)
12	251	94.7 - 239.7 (167.2)	11.9 - 33.9 (22.9)
Minor Pasture Units			
A	17	10.1 - 23.3 (16.7)	0.92 - 2.8 (1.9)
B	77	35.1 - 90.3 (62.7)	27.7 - 73.3 (50.5)
C	15.5	10.5 - 23.6 (17.1)	0.45 - 1.3 (0.9)
D	25	11.7 - 25.6 (18.7)	3.3 - 7.4 (5.3)
E	83	10.5 - 31.0 (20.8)	3.3 - 9.9 (6.6)
F	31	0.96 - 2.71 (1.83)	0.91 - 2.5 (1.7)
G	26	2.6 - 7.8 (5.2)	2.2 - 6.6 (4.4)
H	52	27.9 - 69.6 (48.7)	2.4 - 7.3 (4.8)

Table 3-2 (continued)

Minor Pasture Units	Acreage	Potential Carrying Capacity (Ave.)	Existing Carrying Capacity (Ave.)
I	55	22.1 - 48.2 (35.2)	5.1 - 14.0 (9.5)
L	13	2.7 - 13.9 (8.0)	1.7 - 5.6 (6.3)
M	41	26.8 - 62.6 (44.7)	1.3 - 3.7 (2.5)
N	12	7.8 - 17.8 (12.8)	3.3 - 7.4 (5.3)

clustering was performed using 4 features which included: band 5; band 7; ratio of bands 5/7; and ratio of bands 4/5. The clusters were then systematically displayed and compared with color infrared photography, and the clusters representing Chamise brushlands, grasslands, and surface water were labeled as such. The clusters were then converted to a film-based map product.

<u>Appendix C</u>

A range site supports a distinctive potential plant community, or combination of plants, that can grow on a site that has not undergone major disturbance. Soils that produce the same kind, amount, and proportion of range plants are grouped into range sites. Range sites can be interpreted directly from the soil map where the relationships between soils and vegetation have been correlated. Properties that determine the capacity of the soil to supply moisture and plant nutrients have the greatest influence on range plants and their productivity. Soil reaction, salt content, and a seasonal high water table are also important.

Total production refers to the amount of vegetation that can be expected from a well-managed range that is supporting the potential plant community. It is expressed in pounds per acre of air-dry vegetation for favorable, normal, and unfavorable years. A favorable year is one in which the amount and distribution of precipitation and the temperatures result in growing conditions substantially better than average; a normal year is one in which these conditions are about average for the area; an unfavorable year is one in which growing conditions are well below average, generally because of low available soil moisture.

Dry weight refers to the total air-dry vegetation produced per acre each year by the potential plant community. All vegetation, both that which is highly palatable and that which is unpalatable to livestock, is included. Some of the vegetation also may be grazed extensively by wildlife and some of it not. Plant species that have special value for livestock forage are

1/ Prepared by Irvin L. Sealander, Range Conservationist, Soil Conservation Service.

mentioned in the description of each soil mapping unit.

Common names are listed for the grasses, forbs, and shrubs that make up most of the potential plant community on each soil.[1] The proportion of each species is presented as the percentage, in dry-weight, of the total annual production of herbaceous and woody plants. The amount that can be used as forage depends on the kinds of grazing animals and on the season when the forage is grazed. All of the vegetation produced is normally not used.

Range management requires, in addition to knowledge of the kind of soil and the potential plant community, an evaluation of the present condition of the range vegetation in relation to its potential production. Range condition is an expression of how the present plant community compares with the potential plant community on a particular kind of soil and range site. The more nearly alike the present kinds and amounts of plants and the potential plant community, the better the range condition. The usual objective in range management is to manage grazing so that the plants growing on a site are about the same in kind and amount as the potential native plant community for that site. Such management generally results in the maximum production of vegetation, conservation of water, and control of erosion. Sometimes, however, a range condition somewhat below the potential fits grazing needs, provides wildlife habitat, or provides other benefits, as well as protecting soil and water resources.

Clayey Range Site Soils of the Agueda, Ayar, Botella variant, Diablo, Linne, Los Osos, Nacimiento, Sespe, Todos and Zaca series are in this site. The topography varies from nearly level or gently sloping to steep, occasionally very steep. Slopes range from 2 to 75 percent, but more than half are 30 to 50 percent. Elevations are from 20 to 2600 feet.

The soils are clays, clay loams and silty clay loams. They are 20 to 60 inches or more deep over shale, mudstone, sandstone or alluvium. The soils are well drained, have 3.0 to 12.0 inches available water capacity and a slow or moderately slow subsoil permeability. Runoff is slow to very rapid and erosion hazard is slight to high depending on the steepness of slope.

This site has an open cover of grass. Some areas have scattered oak trees or shrubs. If this site is producing at potential, about 70 percent of the plant cover is Wild Oats[2], Soft Chess, Bur-clover, Filaree and other preferred plants, including Needlegrass and other remnant perennial grasses. Approximately 20 percent is Ripgut Brome, Foxtail Barley and other desirable plants. When the soils are moist late in spring, annual weeds may make up more than 10 percent of the plant cover.

The estimated total annual yield[3] is 2,500 pounds per acre in favorable years and 1,200 pounds per acre in unfavorable years. The estimated total annual yield that livestock and wildlife can graze is 2,000 pounds per acre in favorable years and 900 pounds per acre in unfavorable years.

Soils of this site on slopes of 50 percent or less are well suited to seeding with adapted annual grasses and legumes. Seeding can increase yields in depleted areas two to four times. Fertilization can double the yields in years of favorable rainfall; but does not significantly increase yields in years of low rainfall.

2/ Scientific names of plants mentioned in the range sites are listed at the back of this section.

3/ Estimated total annual yield: Total above-ground growth during a single production year, excepting only growth due to increase in stem diameters of trees and shrubs expressed as air-dry weight. Also excluded is all plant residues of previous production years.

Mapping unit Argixerolls and Xererts, landslide areas (AE) are included in this site. Runoff is medium to rapid and erosion hazard is high. Available water capacity and effective rooting depth are variable. Potential yields are less than those of the other soils in this site.

Claypan Range Site Soils of the Concepcion, Milpitas, Positas and Tierra series are in this site. The topography varies from nearly level or gently sloping to strongly sloping and steep. Slopes range from 0 to 50 percent but almost three-quarters are from 9 to 15 percent. Elevations are from 30 to 1600 feet.

The soils are sandy loams, fine sandy loams and loamy sands that have a claypan subsoil. Some are stony. They are 4 to 50 inches deep over the dense clay subsoil and developed in mixed alluvium or water and wind-deposited sediments. They are moderately well drained. Available water capacity is generally 1.5 to 6.0 inches. Subsoil permeability is very slow. Runoff is slow to very rapid. Erosion hazard is slight to very high. The soils generally are slightly to strongly acid with mildly or moderately alkaline subsoils.

This site has an open cover of grass and scattered California Buckwheat and California Sagebrush with occasional scattered oaks. It is producing at potential, about 70 percent of the plant cover is a mixture of Wild Oats, Soft Chess, Filaree and other preferred plants, including Needlegrass and other remnant perennial grasses. Bur-clover occurs but is not as extensive as on the Clayey Site. Approximately 20 percent is Ripgut Brome, Foxtail Fescue and other desirable plants. No more than 10 percent is Red Brome, Nitgrass, California Sagebrush, California Buckwheat or other undesirable plants. In some years, Tarweed is dominant on well managed sites.

The estimated total annual yield ranges from 1,300 pounds per acre in favorable years to 500 pounds per acre in unfavorable years. The estimated total annual yield that livestock and wildlife can graze ranges from 1,000 pounds per acre in favorable years to 350 pounds per acre in unfavorable years.

All except those soils with slopes over 30 percent are well suited to brush management and to seeding with adapted annual grasses and legumes. These practices can increase yields in depleted areas two to four times. Fertilization can double yields in years of high rainfall, but does not significantly increase yields in years of low rainfall.

Loamy Range Site Soils of the Crow Hill, San Andreas and Santa Lucia series are in this site. The topography varies from strongly sloping to steep, occasionally very steep. Slopes range from 9 to 75 percent but more than half are less than 50 percent. Elevations are from 100 to 1900 feet.

The soils are fine sandy loams, silty clay loams and shaly clay loams, sometimes stony or gravelly or with coarse shale fragments. They are 20 to 40 inches deep over soft sandstones and shales. All are well drained. Available water capacity is 2.0 to 8.0 inches and subsoil permeability is moderately rapid to moderately slow. Runoff is medium to very rapid and erosion hazard is moderate to very high depending on the slopes.

This site has a cover of grass frequently with patches of open to dense stands of oak. Scrub Oak and other brush may occur on eroded or severely eroded areas and on the north slopes. If it is producing at potential, about 70 percent of the plant cover is Wild Oats, Soft Chess, Filaree and other preferred plants including Needlegrass and other remnant perennial grasses. Approximately 20 percent is Ripgut Brome, Foxtail Barley and other desirable plants, and 10 percent is Nitgrass, Wild Mustard, Fiddleneck and other undesirable plants. When the soils are moist late in spring, annual weeds may make up more than 10 percent of the plant cover.

The estimated total annual yield is 2,100 pounds per acre in favorable years and 1,000 pounds in unfavorable years. The estimated total annual yield that livestock and wildlife can graze is 1,500 pounds per acre in favorable years and 700 pounds per acre in unfavorable years.

Soils of this site are well suited to seeding with adapted grasses and legumes except where slopes are too steep or the soil too stony for use of machinery.

Seeding can increase yields 2 to 4 times in depleted areas. Fertilization can double yields in years of favorable rainfall; but does not significantly increase yields in years of low rainfall.

Shallow Loamy Range Site Soils of the Capitan, Gaviota, Lodo, Lopez, Maymen and Montara series are in this site. The topography generally is steep to very steep, occasionally strongly sloping or extremely steep. About nine-tenths of the slopes are steeper than 30 percent and in a few instances extend to well over 75 percent. Elevations are mostly 100 to 2,000 feet, occasionally to 4,700 feet.

The soils mostly are sandy loams, fine sandy loams, clay loams and clays that are 4 to 20 inches deep over sandstone, shale, conglomerate and serpentinetic rocks. Most frequently the soils are stony, cobbly, gravelly, or shaly, have large boulders on the surface. They are well to somewhat excessively drained and have a moderate or moderately slow subsoil permeability. Available water capacity is 0.5 to 3.0 inches. Runoff is medium to very rapid and erosion hazard is moderate to very high.

This site has a plant cover of annual grass or open brush on smoother slopes and open to dense brush on steeper slopes. At lower elevations California Sagebrush, California Buckwheat and Purple Sage are dominant. As elevations increase, these shrubs are mixed with and replaced by Ceanothus, Chamise, Scrub Oak, Manzanita and other Chaparral species.

If this site is producing at potential, about 50 percent of the plant cover is Wild Oats, Soft Chess, Filaree and other preferred plants. About 20 percent is Red Brome, Wild Barley, Nitgrass and other desirable and undesirable grasses and forbs and 30 percent is shrubs.

The estimated total annual yield ranges from 800 pounds per acre in favorable years to 300 pounds in unfavorable years. The estimated annual yield that livestock and wildlife can graze ranges from 300 pounds per acre in favorable years to 100 pounds in unfavorable years.

Shallow Loamy-Rock Outcrop Complex Range Site Soils of the Capitan, Gaviota and Lodo series intermingled with rock outcrop are in this site. This site is similar to the Shallow Loamy Site except that from 30 to 70 percent of the surface is rock outcrop or large boulders. Nearly all slopes are over 50 percent and few of the areas have slopes greater than 75 percent.

Because of the presence of rock outcrop, the potential annual yields are from 30 to 70 percent less than those of the Shallow Loamy Site.

Sandy Range Site Soils of the Arnold and Baywood series are in this site. The topography is nearly level to steep and occasionally very steep. Slopes range from 2 to 75 percent; about three-fourths are less than 30 percent. Elevations are from 20 to 800 feet.

The soils are wind-deposited loamy sands. Arnold soils are 50 to 60 inches deep over soft sandstone. Baywood soils are over 60 inches deep over loose loamy sand and sand deposits. All are somewhat excessively drained and have rapid subsoil permeability. Runoff is slow to medium on slopes less than 30 percent and rapid on steeper slopes. Erosion hazard is moderate to high. Average water capacity is 2.5 to 6.5 inches.

This site has an open cover of brush and a sparse to moderately dense understory of herbaceous plants. Trees and shrubs are abundant in some areas on north slopes. The brush cover is dense in some upland areas near the coast. If this site is producing at potential, approximately 50 percent of the plant cover is a mixture of Soft Chess, Wild Oats, Filaree and other preferred plants. No more than 20 percent is desirable Ripgut Brome or Red Brome, Nitgrass and other undesirable plants. Approximately 30 percent is California Sagebrush, Sawtooth Goldenbush, California Buckwheat and other shrubs.

The estimated total annual yield ranges from 1,500 pounds per acre in favorable years to 600 pounds per acre in unfavorable years. The estimated total annual yield that livestock and wildlife can graze ranges from 1,000 pounds per acre in favorable years to 300 pounds per acre in unfavorable years.

The soils of this site on slopes of 30 percent or less are suited to brush management and seeding to adapted annual grasses and legumes. Range seeding can double forage production on depleted areas.

List of Plants
Mentioned in this Appendix

Common Name	Scientific Name
Bur-clover	Medicago hispid
California Buckwheat	Eriogonum fasciculatum
California Sagebrush	Artemisia californica
Ceanothus	Ceanothus spp.
Chamise	Adenostoma fasciculatum
Deervetch	Lotus scoparius
Fiddleneck	Amsinckia spp.
Filaree	Erodium spp.
Foxtail Barley	Hordeum leporinum
Foxtail Fescue	Festuca megalura
Goldenbush	Haplopappus spp.
Laurel Sumac	Rhus laurina
Lupine	Lupinus spp.
Manzanita	Arctostaphylos spp.
Needlegrass	Stipa spp.
Nitgrass	Gastridium ventricosum
Oak	Quercus spp.
Poison-oak	Rhus diversiloba
Purple Sage	Salvia leucophylla
Red Brome	Bromus rubens
Ripgut Brome	Bromus rigidus
Sawtooth Goldenbush	Haplopappus squarrosus
Scrub Oak	Quercus dumosa
Soft Chess	Bromus mollis
Sugar Bush	Rhus ovata
Sumac	Rhus spp.
Sycamore	Platanus racemosus
Tarweed	Hemizonia spp.
Tule	Scirpus spp.
Wild Mustard	Brassica spp.
Wild Oats	Avena fatua
Willow	Salix spp.

References

Bowden, L. W. et al. 1971. "Remote Sensing of Southern California and Related Environments: Mapping Vegetation Associations with the use of High Altitude Color Infrared Imagery". University of California Department of Geography, Los Angeles and Riverside, California. Contract # USDI 14-08001-10674.

Department of Agriculture - Soil Conservation Service. 1977 "Soil Survey of the South Coast of Santa Barbara County - Interim Report".

Haller, J. R. and Chetum. 1976. "Vegetation Classification for the University of California Wilderness Refuge System". Unpublished.

Jensen, W. - University of California Cooperative Agricultural Extension Service. Santa Maria, California.

Munz, P. A. 1974. A Flora of Southern California. University of California Press. Berkeley, California.

Ornduff, R. 1974. Introduction of California Plant Life. University of California Press. Berkeley, California.

Santa Barbara County Planning Department. 1979. Conservation Element to the General Plan. Santa Barbara, California.

Smith, C. F. 1976. A Flora of the Santa Barbara Region, California. Santa Barbara Museum of Natural History. Santa Barbara, California.

Smith, G. 1976. "Wildlife and Vegetation Resources for the City of San Buenaventura and Associated Areas." Ventura County Publics Works Agency, Ventura, California.

CHAPTER 3

PART 5

Perched Water Study

Authors: Elaine Ezra
Larry Tinney

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1.0 INTRODUCTION

Previous research efforts (NSG-7220, 1979) have demonstrated that thermal infrared and Landsat MSS remote sensing data offer considerable potential in providing data useful to drainage related studies. The primary goal associated with this project was to delineate regional boundaries and trends of shallow perched water tables in the Kern County portion of the Southern San Joaquin Valley, as a step toward better management of such areas.

Specific research objectives included:

- Acquisition of U-2 thermal day/night imagery over the Kern County, California test site.
- Acquisition of coincident field data for verification of results.
- Analysis of thermal infrared imagery using photo interpretation and digital techniques.
- Analysis of Landsat imagery using digital enhancement techniques.
- Creation of a probable perched water table map for Kern County, California.

Subsequent sections discuss the results and problems encountered during this reporting period, as well as future research to be conducted on this and related topics.

2.0 THERMAL INFRARED DATA ACQUISITION, FIELD VERIFICATION, ANALYSIS

Two U-2 high altitude thermal day/night flights were flown over the San Joaquin Valley test site; the first June 13, 1979, and the second October 3, 1979. Unfortunately, due to system failures within the thermal scanner, data adequate for image interpretation or digital analysis was never acquired for either of these flights. Ground verification data, nevertheless, was coincidently collected during both of the day/night flight periods. Sampling sites were located at piezometric depth-to-water table well locations in the Wheeler Ridge-Maricopa Water Storage District. Surface temperature measurements using a Barnes Instatherm radiometer and YSI thermal probes were collected at each of the sample sites, as well as crop type and condition information. A continuous thermal recording unit for temperature profile data was set up at a single site, which continued collecting data over a one-month period.

Field data collected during this project will be used as supplemental information in a proposed spin-off research project for FY 81. This project will examine thermal inertia data and its utility for detecting shallow water tables. Thermal inertia images will be digitally produced from low, high and satellite altitude thermal infrared imagery for assessment of different spatial resolutions and recognizable trends in drainage conditions (i.e., per field, district and county, and state levels).

3.0 DIGITAL ENHANCEMENT OF LANDSAT MSS DATA

The utility of spectral reflectance differences between crop canopies in perched as compared to non-perched areas was investigated. Spectral reflectances are expected to differ between crop canopies located in well-drained areas and stressed or damaged vegetation in poorly drained and/or saline soils. In bands 6 and 7 stressed or damaged fields would typically exhibit reduced spectral reflectances. Application of different biomass ratios, transformations, and digital stretches may enhance these spectral reflectance differences.

By digitally creating a vegetative mask and stretching the reflectance values within that mask for each of the spectral bands, subtle reflectance differences can be greatly enhanced. Figure 3-18 is an example of a digital stretch performed on a July 11, 1978 Kern County Landsat frame. The area

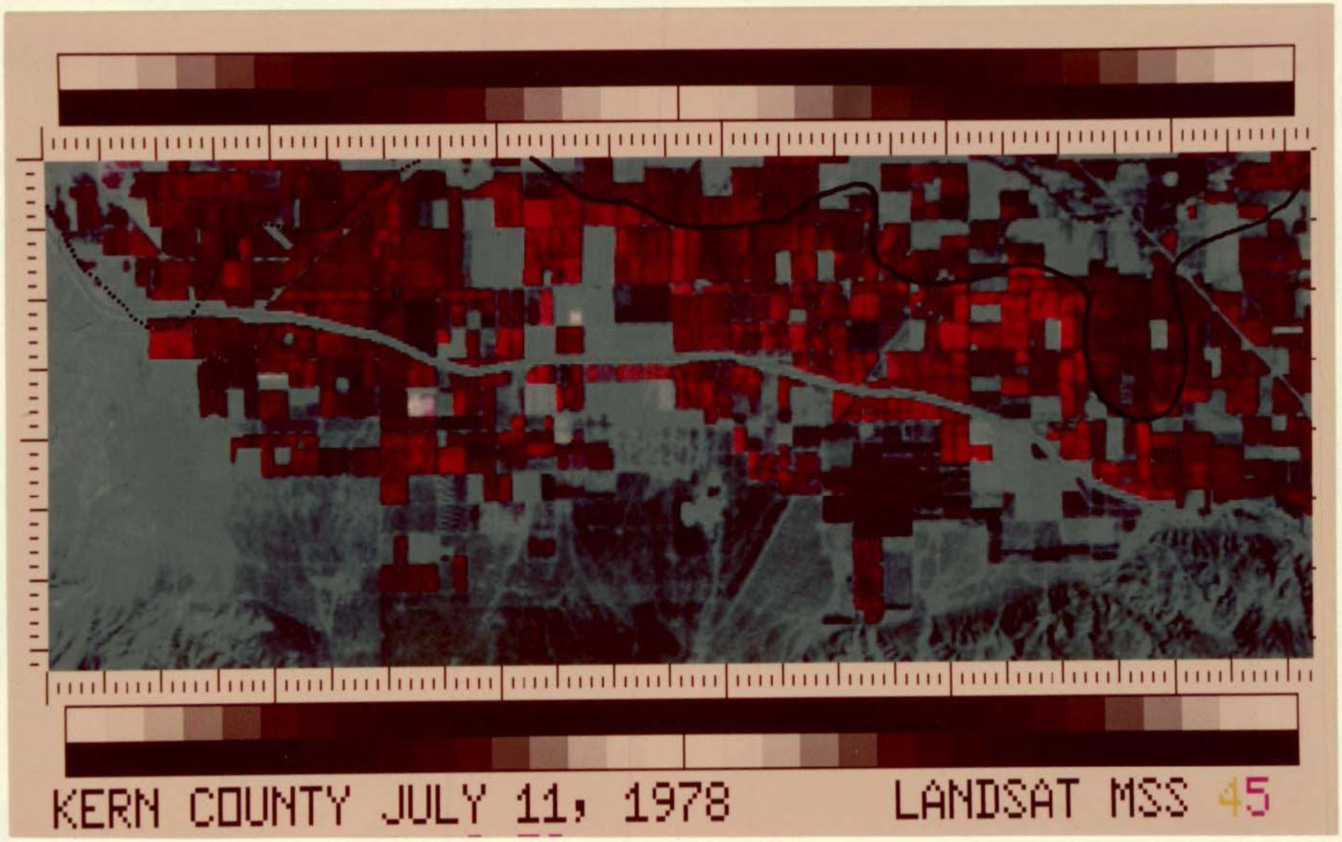

Figure 3-18. Vegetation stretch of July 11, 1978 Wheeler Ridge-Maricopa Water Storage District test site, using bands 4, 5, and 7. Solid contour line represents 0-5' depth-to-water table contour constructed from test well measurements. The dashed line represents an expected problem area where no test well information is available.

displayed is the Wheeler Ridge-Maricopa test site. The solid contour in the upper right represents the 0-5' depth-to-water table contour as constructed by Wheeler Ridge-Maricopa Water Storage District personnel from June 1978 data. The darker signatures of stressed or damaged vegetation correspond well within this contour. The brighter red tones outside this contour represent healthy vegetation, with a higher spectral reflectance. The dashed contour in the upper right corner of the image is a region in which there is no depth-to-water table information available; however, it is expected that there exists the same type of shallow water table pattern as found in the northeastern part of the district. Figure 3-19 is a standard color composite of the Kern County portion of the July 11, 1978 Kern Landsat frame. This is shown in contrast to Figure 3-20, which is the vegetation stretch covering most of Kern County. (Figures 3-18 and 3-19 cover the same area; however, Figure 3-20 has a 1.5 times enlargement.) The Wheeler Ridge-Maricopa test site can be seen in the lower right portion of the image. In this image, features other than vegetation, have been masked out. The dashed contour line delineates the region that appears to either display dark soil patterns indicative of clay lake beds, or discontinuities in the reflectance patterns of the crop canopies. These are regions which would tend to indicate shallow water tables or potential problem areas. The topic of biomass ratios, tranformations and digital stretches for enhancing vegetative condition differences and resultant spectral reflectance differences in poorly drained saline soils is Ms. Ezra's thesis topic, and will be fully discussed in the next reporting period.

4.0 FUTURE WORK

As a result of contacts with the California Department of Water Resources and the Kern County Water Agency during this project, the potential role of remote sensing to the California Master Drain Plan was defined as: 1) delineation of perched water boundary regions; and 2) monitoring changes in irrigation patterns (i.e., furrow irrigation to sprinkler) as input to perched water table growth estimates. However, the utility of results from the project in terms of immediate management action was questionable, as it appears there are many economical and political considerations involved in determining the placement of the Master Drain. These considerations are apparently more important than definition of a physical boundary for the perched water table problem areas. Therefore, it was decided that the emphasis of the project would be better directed towards a more demonstrably useful application. A meeting was held with the U. S. Salinity Lab in Riverside, a branch of USDA, to discuss any interest they might have in using remote sensing techniques for stratifying vegetated stress conditions in ground-based sampling activities. This meeting resulted in a very favorable response from the Lab personnel, indicating a real need for better sampling site location.

Salinity and associated drainage problems are a widespread concern in many arid agricultural environments. The effects of these conditions result in reduced crop yields, and ultimately the loss of highly productive lands. Present methods of monitoring salinity levels in soils is through ground based soil sampling. This method is both time-consuming and costly. In addition, salinity is not spatially continuous. Limited numbers of soil sample points may not include regions within large fields where salinity or drainage problems exist. Remote sensing offers the potential for improvement of ground based soil sampling. Using color infrared aerial photography, fields can be stratified according to vegetation and soil condition as surrogate measures of salinity. This

Figure 3-19. Standard color composite of July 11, 1978 Kern County portion of a Kern Landsat frame.

~~3-118~~

311

Figure 3-20. Vegetation stretch of July 11, 1978 Kern Landsat frame (same as above). Features other than vegetation have been masked out, and reflectance values within the vegetation digitally stretched to enhance subtle differences. The dashed line delineates the region interpreted as probable perched areas based upon soils and vegetation canopy.

should reduce the number of samples required, and thus the associated costs. This also would improve the measurement of salinity levels through better sampling design.

4.1 Objectives

The objectives of this research are as follows:

- Through joint cooperation with the U. S. Salinity Laboratory at Riverside we hope to:
    1) Establish criteria for stratifying vegetation and soils.
    2) Acquire data from ongoing research at Lost Hills, California as a basis for verification of our results.
- Devise a systematic methodology for stratification;
- Devise a change detection methodology for determining where problem areas are expanding;
- create a procedural manual designed for individual farmers and soil specialists to use for taking action on a per field basis;
- Devise a feasible system whereby individual farmers and soil specialists can receive and act on this information.

4.2 Approach and Procedures

The intent of this proposed research is to devise a methodology using remote sensing techniques for stratifying fields, based upon soil and vegetation condition, for more effective salinity sampling strategies. The preliminary steps toward this goal will include a compilation of information leading to understanding the physical basis for interpretation of salinity effects. These general areas of interest are:

- Plant/Soil Interaction
  Physical aspects (how plant responds to varying salinity contents)
- Spectral Characteristics
  (stressed vs. non-stressed vegetation)
- Sampling Designs
  Soil sampling schemes
  Stratification

The U. S. Salinity Laboratory has made data available from current research in the Lost Hills region of Kern County, California. Their research is focused upon determining the effects of varying amounts of salinity upon vegetation, especially cotton. Intensive within-field sampling is being conducted, and includes fields with varying salinity contents throughout the field. We will use this data, in conjunction with coincident U-2 high altitude and commercial low altitude color infrared imagery, to determine the spectral definition of vegetation under different salinity levels and poorly drained soils. We hope to determine the number of stratification levels feasible on a per field basis using photo interpretation techniques. Once we have created a methodology for stratification, we hope to devise a scheme for coverage that would be useful at the individual farm level, and possibly local level.

4.3 Anticipated Results

The final product of this proposed research will be a procedural manual designed to demonstrate a feasible technique using color infrared aerial photography for better soil sample design, as well as the establishment of an operational system for its use when making and implementing management decisions.

This manual will be used as a foundation for a proposed Agricultural Workshop with an emphasis on salinity problems. We have already received a favorable response from NASA Ames Research Center for conducting a U. C. Agricultural Extension training course to transfer the salinity assessment techniques we propose to develop in this project.

4.4 Management Action

A meeting was conducted with the U. S. Salinity Laboratory to discuss the role they will play in this research. Personnel from the Lab will act in an advisory capacity and will review any reports or publications resulting from this research. They also emphasized that there is much interest in stratification of field conditions at both the individual field and regional basis for better sampling strategies, and that they would be interested in adopting any methodology we develop during this project.

We will also work to define the actual users requiring this type of information, in addition to the Salinity Laboratory. We will contact soil consulting firms and other associated consultants operating in the San Joaquin Valley who have expressed interest in this type of capability in the past (attached letter of support). We plan to work closely with the U. C. Agricultural Extension and Farm Advisors to link the utility of this technique to the individual farmers.

Chapter 3

Part 6

Cotton Mapping from Landsat Imagery

Authors: Tara Torburn
Larry Tinney

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1.0 INTRODUCTION

Early season manual and digital mapping of cotton fields can be accomplished through the use of Landsat technology. Techniques developed are targeted to be suitable for implementation by California Department of Food and Agriculture (CDFA) and/or United States Department of Agriculture (USDA) personnel for the Pink Bollworm Program in the San Joaquin Valley, California. The temporal aspect of Landsat coverage makes it particularly suitable for crop identification studies. Results of both manual and machine assisted Landsat-based approaches to the inventory of cotton fields are potentially both feasible and as accurate as current ground-based "windshield" surveys. However, this research indicates that the late May-early June time constraint of producing maps showing the location of cotton fields in the San Joaquin Valley may have to be extended into mid-June. The phenology of cotton as affected by climatological factors -- most importantly, temperature and precipitation -- must be taken into account when determining the deadline for a Landsat-based cotton inventory.

The Landsat-based manual image analysis methodology employed in this research project involved a historical study for the years 1974, 1975, 1976, and 1977, for a test site in the southern San Joaquin Valley, California. Training, or crop identification, keys for a variety of crops grown within the test site were developed. Trained photo interpreters utilized these keys in identifying cotton versus non-cotton on a series of enlarged "false" color composite Landsat images of the test site. The machine assisted Landsat-based digital methodology utilized a 1976 Landsat data set. Jet Propulsion Laboratory's (Pasadena, California) VICAR (Video Image Communication and Retrieval) programs (7) were used to perform an unsupervised clustering; select optimum dates and channels of Landsat data to classify cotton; detail training fields; and perform supervised classifications of cotton. Both the manual and digital identifications were compared to the ground truth sources on a field-by-field basis for computing accuracy figures.

Relative accuracies between ground truth sources used in this research are in the low 90's. Overall accuracies of the manual approach for the historical study range from a low of 57% to a high of 92%. Accuracies of the digital approach range from 73% (for a one-date early season classification) to 94% (for a three-date full season classification). The high ranges of these distributions are comparable to present accuracies obtained by the operational agencies conducting surveys of cotton fields in the southern San Joaquin Valley. Given timely coverage and delivery of Landsat data the conclusion of this research is that satellite remote sensing does offer the potential for assisting in the efforts to control pink bollworm of cotton.

This research project was incorporated into the Master's thesis of Tara Lee Torburn, "Identification of Cotton Fields from Landsat Imagery in the Southern San Joaquin Valley, California" (12).

2.0 STUDY AREA: SAN JOAQUIN VALLEY, CALIFORNIA

An area of approximately 45 square miles within the Wheeler Ridge-Maricopa Water Storage District (WR-M WSD), located in Kern County at the southern end of the San Joaquin Valley, has been chosen as a test site for exploring the feasibility of cotton mapping techniques based on analysis of multidate Landsat imagery.

The Geography Remote Sensing Unit (GRSU), University of California, Santa Barbara (UCSB), has been conducting research in this region for several years.

This research has resulted in the compilation of an extensive collection of weather, crop, and Landsat data and imagery for the years 1973-1978. Within this test site are found over 15 different crops (Table 3-3), with cotton comprising about 50% of the cropped fields when statistics are averaged for the four years of this study.[1]

Climatically the San Joaquin Valley is characterized by cool wet winters and warm/hot dry summers. Temperatures average 45°F in the winter and 85°F in the summer (4) while precipitation averages less then 6½ inches per year, with typically dry summers (1). The dry summers have made it necessary to irrigate crops in the San Joaquin Valley and, in the test site, nearly 100% of the crops are irrigated (6). The climatic conditions in the southern San Joaquin Valley make this an ideal place to grow cotton, where more than 90% of the State's cotton is produced (Figure 3-21).

Since the San Joaquin Valley is California's principal cotton growing region, it is here that CDFA and USDA have concentrated their cotton mapping, trap placement, and trap monitoring efforts for the Pink Bollworm Program. The pink bollworm has already become established in the three major agricultural areas in southern California -- the Imperial, Coachella, and Palo Verde Valleys (3). Strict regulations were set down in 1972 to help control the population increase and geographic expansion of the pink bollworm from these heavily infested areas to the San Joaquin Valley. Presently, control measures appear to be keeping pink bollworm population levels in check.

Table 3-3

Crop Types Within the Test Site

Crop	1974	1975	1976	1977
Cotton	62.3%	42.0%	56.8%	41.0%
Small Grains	3.1	15.0	14.4	6.0
Lettuce	1.7	-	2.6	2.0
Peppers	1.4	0.6	1.7	0.6
Melons	6.9	10.4	4.9	3.7
Tomatoes	11.7	9.2	4.9	3.2
Sugarbeets	3.7	9.2	6.3	1.4
Onions	1.1	3.7	2.6	3.7
Carrots	0.3	0.9	0.6	2.6
Potatoes	0.6	0.9	-	0.9
Alfalfa	0.9	0.9	1.2	1.2
Safflower	0.3	3.7	-	-
Fallow	3.1	3.4	1.1	31.8
Natural Vegetation	2.0	4.6	2.9	3.4

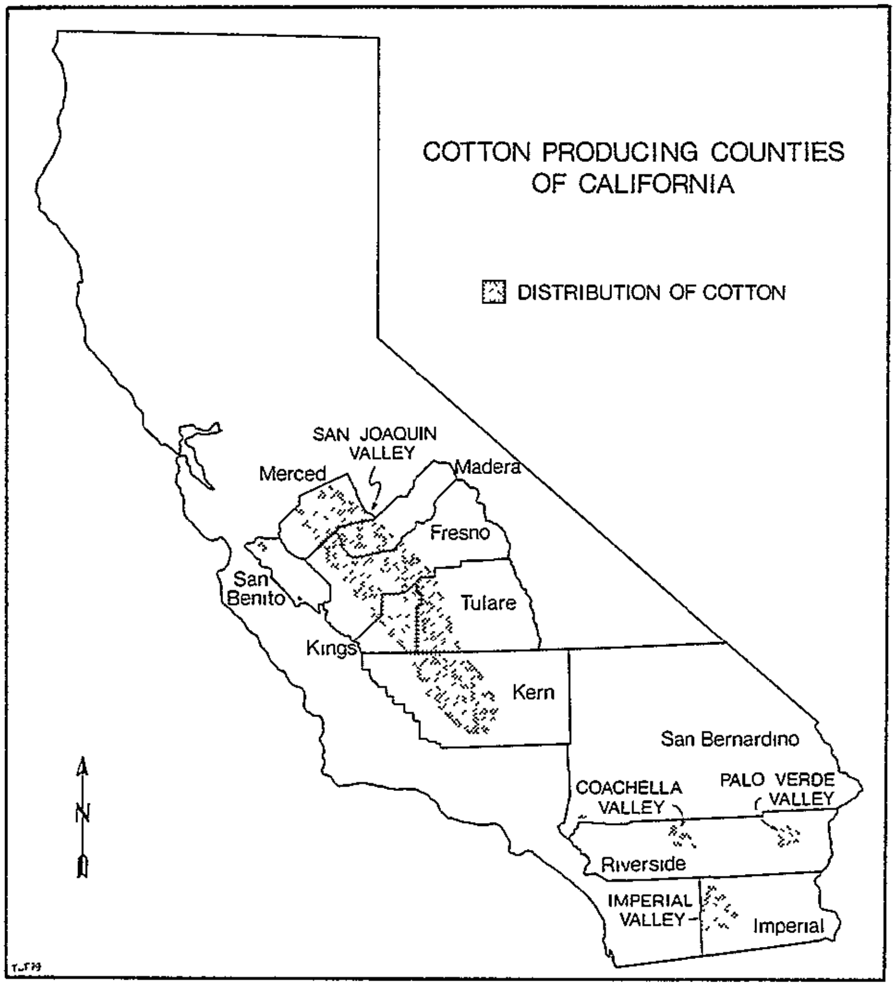

Figure 3-21. California cotton production is concentrated in the San Joaquin Valley, with production also found in the Imperial, Coachella, and Palo Verde Valleys. (From Durrenberger and Johnson, 1975, p. 82.)

3.0 DATA ACQUISITION

For a historical study to develop manual and digital cotton mapping techniques for the Pink Bollworm Program, a variety of data needed to be collected. These data, in turn, needed to be brought to a uniform scale suitable for accurate comparison and analysis. Data necessary for performing the manual interpretations and digital classifications of cotton included: "ground truth" maps showing the location of all cotton fields within the study area for 1974, 1975, 1976, and 1977; for the manual approach, January through May/early June cloud-free Landsat images of the study area for 1974, 1975, 1976, and 1977; and maps (overlays) showing field boundary locations for all fields in the test site for 1974, 1975, 1976, and 1977. For the digital approach, a preexisting Landsat digital data set of the study area was used for a series of 1976 digital classifications of cotton.

3.1 GROUND TRUTH DATA

During April and May of each year, USDA conducts a "windshield survey" in Kern and Tulare counties to map the location of cotton fields for the Pink Bollworm Program. CDFA conducts the same type of survey for the remaining cotton growing counties in the San Joaquin Valley (Kings, Fresno, Merced, and Madera). Cotton maps produced by USDA which cover the test site for this research project have been used as one source of "ground truth" data.

Each spring Wheeler Ridge-Maricopa Water Storage District maps all acreage within the Water Storage District boundaries as to crop type, fallow conditions, or natural vegetation. A fall "change map" is also produced. This survey, like the USDA and CDFA surveys, is ground-based. Discrepancies in cotton field locations are known to exist between the USDA and WR-M WSD maps. Past investigations conducted by GRSU have noted inaccuracies in the WR-M crop survey maps.

In 1977 Kern County was also mapped by the California Department of Water Resources (DWR) during late summer-early fall in their agricultural land use update mapping program for the state.

For the purpose of this research these ground truth sources are assumed to be 100% correct. It is these maps against which interpretations accomplished in this research have been compared even though known inaccuracies do exist within these data. This conclusion is supported in the following analysis.

Although most ground-based surveys claim close to 100% accuracy, comparisons between survey maps of the study area (Table 3-4) reveal relative inaccuracies inherent in typical conventional survey programs. Overall accuracies for the test site in this research are in the low 90's, with a low of 89% and a high of 96%. The variations in these sources may be due to the type of survey and time when the survey was being conducted. USDA is concerned only with locating cotton fields, and conducts its survey during April and May. WR-M WSD is interested in identifying all crop types, thereby allowing for misidentification of cotton. This survey is also carried out in Spring. DWR is interested in all types of land use and crop types, but conducts its survey much later in the growing season, with aerial photography flown in July, and ensuing field work lasting into November. This method allows for more positive crop identification, especially for cotton, a crop which is at its growing peak in July-August. Thus, the DWR survey is probably the most accurate with respect to positive identification of cotton.

3.2 LANDSAT DATA

The NASA Landsat satellite series (originally named Earth Resources Technology Satellite, or ERTS) presently has three satellites orbiting the earth at an altitude of approximately 565 miles. Landsat 1 was launched July 23, 1972,

Table 3-4

Relative Accuracies of Cotton vs. Non-Cotton as Mapped by Different Agencies in the Wheeler Ridge-Maricopa Test Site

1974 USDA	WR-M WSD Cotton	WR-M WSD Non-Cotton	Total Fields	% Corr
Cotton	206.5	11	217.5	94 9
Non-Cotton	11.5	121	132.5	91 3
Total	218	132	327 5 / 350	
% Corr	94 7	91 7		93.6

1977 USDA	WR-M WSD Cotton	WR-M WSD Non-Cotton	Total Fields	% Corr
Cotton	116.5	13	129.5	90.0
Non-Cotton	26 5	193	219 5	87.9
Total	143	206	309 5 / 349	
% Corr	81.5	93.7		88.7

1975 USDA	WR-M WSD Cotton	WR-M WSD Non-Cotton	Total Fields	% Corr
Cotton	128 75	5 25	134	96.1
Non-Cotton	8 5	184 5	193	95 6
Total	137 25	189 75	313.25 / 327	
% Corr	93 8	97 2		95.8

1977 USDA	DWR Cotton	DWR Non-Cotton	Total Fields	% Corr
Cotton	125.25	4 25	129 5	96 7
Non-Cotton	15 75	203 75	219 5	92 8
Total	141	208	328 5 / 349	
% Corr	88.8	98 0		94 1

1976 USDA	WR-M WSD Cotton	WR-M WSD Non-Cotton	Total Fields	% Corr
Cotton	185 25	10 25	195.5	94 8
Non-Cotton	17	134 5	151 5	88 8
Total	202 25	144 75	319.75 / 347	
% Corr	91 6	92 9		92 2

1977 WR-M WSD	DWR Cotton	DWR Non-Cotton	Total Fields	% Corr
Cotton	125 5	17 5	143	87 8
Non-Cotton	15 5	190.5	206	92.5
Total	141	208	316 / 349	
% Corr	89 0	91.6		90.5

with an expected life-span of one year. Retired January 7, 1978, Landsat 1 produced data for over five years. Landsat 2, launched January 19, 1975, is no longer functioning operationally. Landsat 3, launched March 5, 1978, is functioning. All three satellites are in an 18-day sun-synchronous orbit. Presently Landsat 3's ground track follows Landsat 2's by nine days. While Landsat 2 was still functioning, the two satellites provided coverage of the same geographic area every nine days.

The primary sensor system on board Landsats 1, 2, and 3 which has been employed in this research project is the multispectral scanner (MSS). The MSS images in four different wavelengths of the electromagnetic spectrum. These four wavelengths are referred to as MSS bands 4, 5, 6, and 7, and image in the following wavelengths: band 4, .5-.6; band 5, .6-.7; band 6, .7-.8; and band 7, .8-1.1 micrometers. These bands correspond, respectively, to the green and red wavelengths in the visible portion of the electromagnetic spectrum, and two near-infrared wavelengths just beyond the visible.

Spectral reflectance data are simultaneously digitally recorded by fiber optics detectors on the satellite on a scale of digital number (or DN) values ranging from 0-127 for bands 4, 5, and 6, and on a scale of 0-63 for band 7. These data are transmitted to a receiving station where they are linearly stretched for each channel to a scale of 0-255. Using the stretched digital data, separate images are produced for each one of the four bands; 0 corresponds to black (absence of spectral reflectance at that wavelength) and 255 to white (maximum spectral reflectance at that wavelength), with varying shades of gray between. The images cover an area of 115 miles by 115 miles, and each picture element, or pixel (resolution cell), corresponds to approximately 1.1 acres (10).

MSS bands 4, 5, and 6, or 4, 5, and 7, can be combined to produce a "false color" image by projecting band 4 through a blue filter, band 5 through a green filter, and band 6 or 7 through a red filter. The resulting color composite image resembles a color infrared photograph; that is, vegetation is typically depicted as a red color. When the stretched data is left in the digital format, it is referred to as a Computer Compatible Tape, or CCT, and contains all four MSS bands for a scene.

Landsat's ability to repeatedly collect data in a consistent format through time makes it particularly suitable for crop identification. Crops often exhibit a distinctive growth or phenological cycle throughout the year which, when observed in relation to other crops in a given region, can be employed to aid in the identification of particular crops. The phenological cycle of cotton in the southern San Joaquin Valley is seen in Figure 3-22 and that of small grains in Figure 3-23. By comparing these two cycles, it is obvious that, given a full year's Landsat data, these two crops would be separable.

The major problem in identifying cotton for the Pink Bollworm Program is the time constraint of producing maps showing the location of all cotton fields. This location identification must take place by early June. For this reason, only Landsat data acquired through May of each year may by used. In this time frame, cotton has just been planted and is at most only a few inches tall. Therefore the mapping of cotton fields from Landsat imagery is largely accomplished through elimination of vegetated and fallow fields.

Prior GRSU research has shown that the test site is most often contained in two Landsat scenes on sequential overpass dates, and occassionally in a third scene. It was necessary to determine dates of coverage during the January-May/early June timeframe of this project. A computerized imagery search ("Geographic Computer Search"), a free service provided by USGS's EROS Data Center at Sioux Falls, South Dakota (13), was requested for the three scenes: the "Lancaster"

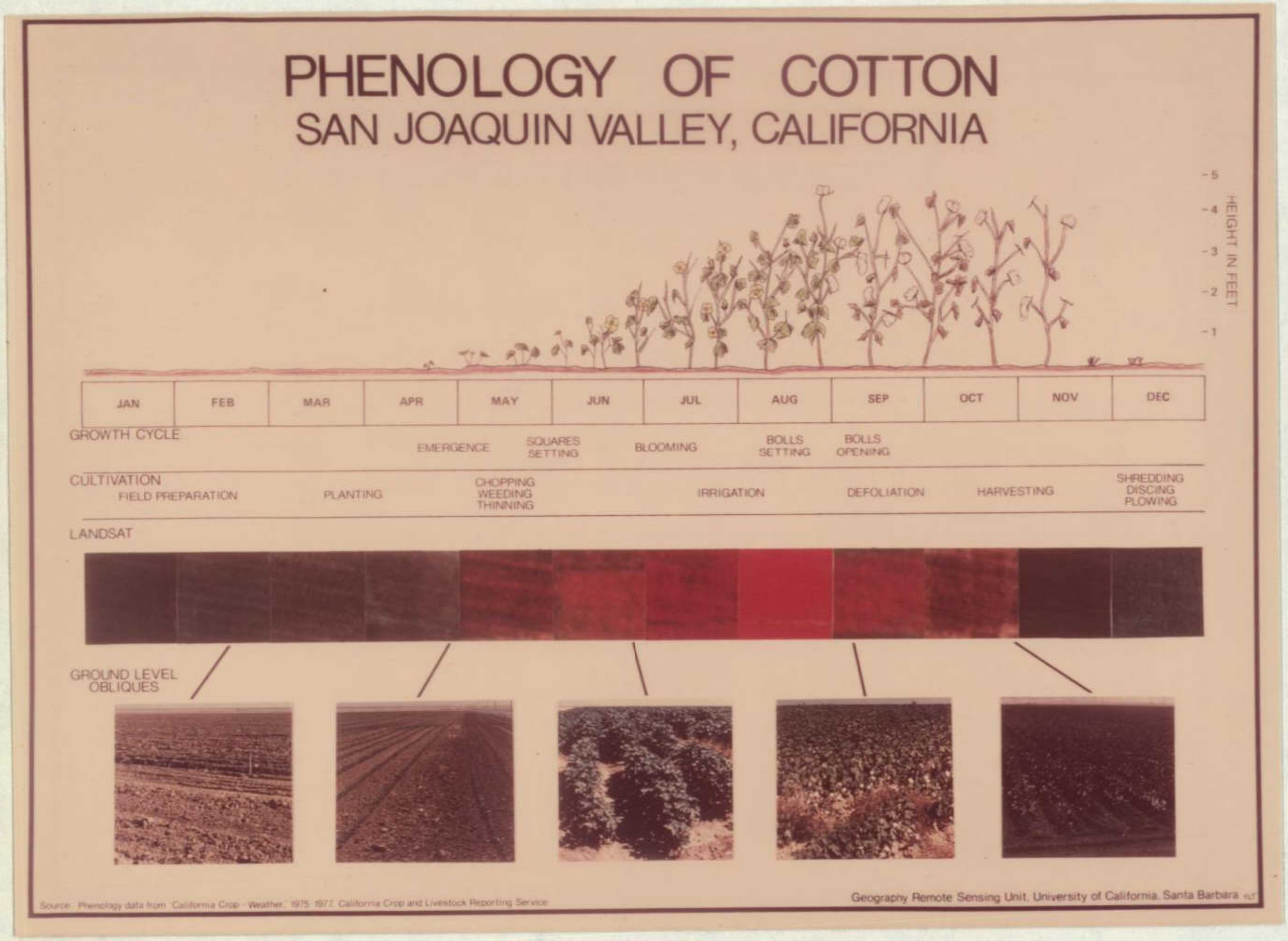

Figure 3-22. Phenological cycle of cotton for the San Joaquin Valley, California. The Landsat "chips" are greatly enlarged false color composites of a cotton field as viewed by Landsat during the year.

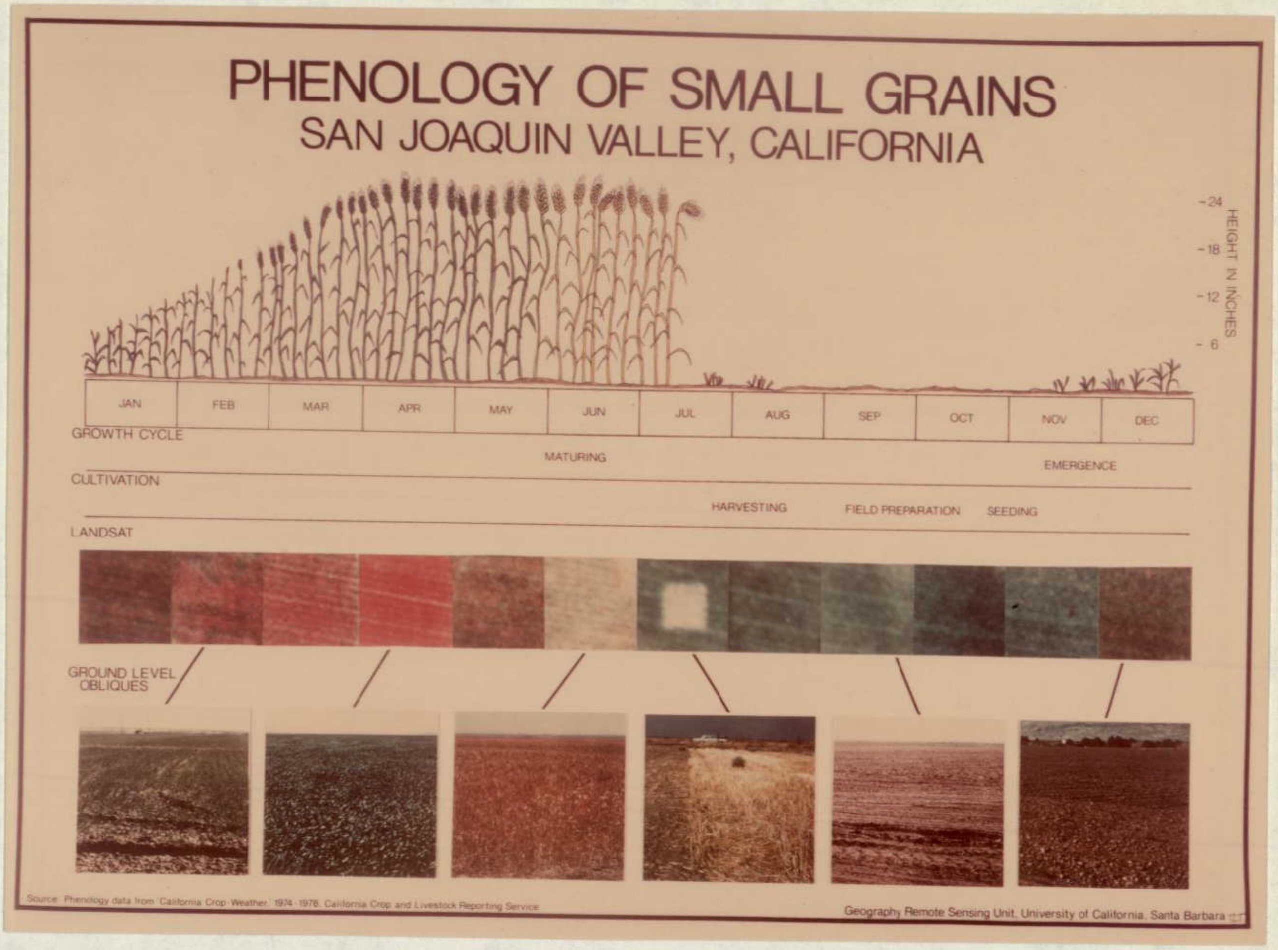

Figure 3-23. Phenological cycle of small grains for the San Joaquin Valley, California. The Landsat "chips" are greatly enlarged false color composites of a small grains field as viewed by Landsat during the year.

image, Landsat worldwide reference system (WRS) coordinates path 44, row 36, the "Santa Barbara" image, path 45, row 36, and the "Kern County" image, path 45, row 35. By analyzing material provided by the search, it was possible to determine relatively cloud-free overpass dates and to confirm coverage of the test site on the Lancaster, Santa Barbara, and/or Kern County scenes. MSS bands 4, 5, and 7 of the selected overpasses were ordered from the EROS Data Center.

When the black-and-white 1:1,000,000 scale transparencies were received, they were further analyzed for cloud cover and quality. Cloud-free 2.2 inch chips encompassing the test site were cut out of each usable image. These were then optically color combined on the I^2S Additive Color Combiner. Band 4 was projected through a blue filter, band 5 through green, and band 7 through red.

After the three colors have been balanced so as to reproduce a "false" color infrared image, a 4"x5" positive color transparency of the study area is photographed directly off the color combiner viewing screen. These transparencies are then photographically enlarged and color prints of the test site are made. The final scale is approximately 1:167,000. No effort was made to achieve absolute color control from date to date because of difficulty in maintaining continuous control in both the color combining and photographic system.

For the digital classification, a 1976 MSS CCT data set of the study area was used. This data set includes the western portion of the Wheeler-Ridge Maricopa Water Storage District and surrounding lands covered by three USGS 7½' topographic quadrangles (Pentland, Conner SW, and Coal Oil Canyon). All but a few of the fields in the test site are contained within this data set. The five following scenes comprise the data set:

2465-17502	1 May 76
2501-17492	6 Jun 76
5459-17185	21 Jul 76
5477-17172	8 Aug 76
2627-17455	10 Oct 76

In previous research projects conducted by GRSU personnel, this data set has been registered to within ± ½ pixel and has been sun angle corrected to a constant 39° using the cosine function. For each date there are eight channels of information. These include MSS bands 4, 5, 6, and 7; the Kauth transforms; and an MSS7/MSS5 band ratio. The Kauth transforms, linear preprocessing transformations, are Brightness, Greeness, and Yellowness (8, 9). Table 3-5 gives the transformation matrix for these transforms.

Table 3-5
Kauth Transformation Matrix

Band	Brightness	Greeness	Yellowness	"Non-Such"
MSS4	.33231	-.28317	-.89952	-.01594
MSS5	.60316	-.66006	.42830	.13068
MSS6	.67581	.57735	.07592	-.45187
MSS7	.26278	.38833	-.04080	.88232

(From Lambeck, 1977, p. 17.)

3.3 FIELD BOUNDARY DATA

"Field boundary" overlays for the test site were created in order to compute interpretation accuracies of the historical study on a field-by-field basis. For 1974, 1975, and 1976, field boundary locations were mapped on NASA U2 July-August 1:125,000 scale high altitude aerial color infrared photography. When necessary, larger scale imagery was employed to accurately map field boundaries. The 1:125,000 scale field boundary overlays were then reduced and transferred to the 1:167,000 scale Landsat prints of the study area. For 1977, no U2 imagery of the test site was available at the time the overlays were made. The 1976 field boundary overlay was "updated" for the 1977 season by noting any variations in field boundaries on the 1977 Landsat images. For data analysis purposes only, consecutive numbers were then assigned to each field, starting in the upper left corner of the test site and working left to right to the lower right corner.

4.0 MANUAL METHODOLOGY

Assessment of the potential of the appropriateness of the manual approach for identifying cotton by late May involved administering photo interpretation tests to trained photo interpreters. For these tests interpreters were provided training keys of crops and test prints of the test site for January through May/early June for 1974, 1975, 1976, and 1977. For these manual interpretation tests it was also necessary to create training, or crop identification, keys for various crops growing in the study area. This was accomplished using the Spring Crop Survey conducted by Wheeler Ridge-Maricopa Water Storage District as "ground truth." From this base individual fields of different crops were located on a 1:167,000 scale Landsat print (as previously described). The same fields were then located on all prints for that year, avoiding fields within the test site. Fields that appeared to be questionable as to "ground truth" crop type were not used. This technique was repeated for each of the four years of the study.

4.1 CROP IDENTIFICATION KEYS

To construct the crop identification keys, individual fields which had been identified as to crop type, and numbered for identification purposes only, were cut out of each 1:167,000 scale Landsat false color print. The same crop types were grouped together by field identification number and date on one 5"x8" index card for each year. An attempt was made to have five representative fields of each crop for each year. This procedure was repeated for each usable overpass for 1974-1977. These crop keys were grouped together in notebooks by year.

4.2 TEST BOOKLETS

Test booklets were then compiled for each of the four years of the study. Included in each booklet was a 1:167,000 scale landsat false color print of each usable date. Each of these prints had the test site boundaries outlined to enable the interpreters to properly align the field boundary overlay.

4.3 INTERPRETATION TESTS

Manual interpretation tests were administered to four trained photo interpreters. Each interpreter was supplied with a test booklet and set of training keys for each year, as well as the corresponding field boundary overlays. Grease pencils were provided for marking interpretations on the field boundary overlays. Interpreters were instructed to identify only cotton versus non-cotton, and requested to note the time required for each interpretation. Information provided to the interpreters prior to interpretation included effects of soil type and soil moisture variations on crop signatures. In addition, interpreters were told that cotton represented an average of 50% of the cropped fields in the test site. Interpreters were also free to ask questions concerning the identification tests. In an effort to make the test realistic a number of fields within the test site had been eliminated from the interpretations. These included primarily orchards and vineyards, a nursery, as well as some urban areas. Also eliminated were fields which went beyond the resolution limitations of the enlarged prints -- fields which were too small to clearly identify. In an operational procedure, static features such as these could be eliminated by previous stratification from aerial photographic surveys or ground inventory.

The manual interpretation tests were compared for accuracy against the USDA and WR-M "ground truths" for 1974, 1975, 1976, and 1977, with the addition of the DWR "ground truth" for 1977.

5.0 DIGITAL METHODOLOGY

For exploring the feasibility of digital cotton mapping techniques for the Pink Bollworm Program, supervised VICAR (Video Image Communication and Retrieval) classifications were performed on the 1976 Landsat digital data set. VICAR is a computer software package developed by Jet Propulsion Laboratory (JPL) in Pasadena, California, for facilitating the processing and recording of digital image data (7). In order to remain within the temporal constraints of the Pink Bollworm Program (late May-early June), two one-date classifications were performed using the May 1 digital data and the June 6 digital data. A two-date classification using these two dates was also completed. Finally, a three-date classification using May 1, July 21, and October 10, although not within the cotton mapping time frame of the Pink Bollworm Program, was also performed.[2]

Three steps were involved in the development of this digital classification: first, optimum date/channel selection; second, cluster analysis for refinement of training classes; and third, supervised classification for identification of cotton. For previous GRSU research projects the easternmost topographic quadrangle which covers the study area, Coal Oil Canyon, was chosen as the "training quad" because of the vairety of crop types found within its borders. The other two topographic quadrangles, Pentland and Conner SW quad, were used as "test quads." Two thirds of the test site for this project is contained within the Conner SW quad, and the remaining third falls within the Coal Oil Canyon quad. Unfortunately, some of the training classes therefore fall within the test site.

5.1 DATE/CHANNEL SELECTION

For a previous 1976 digital cotton classification using a six-channel data set -- May, July, October, MSS bands 5 and 7 for each date -- eight training classes had been defined based upon general spectral/temporal appearance. These eight classes included six cotton fields comprising one training class, and seven non-cotton fields each as separate training classes, all located within the Coal Oil Canyon quad. Using these eight training classes as a starting point for determining more detailed training classes, VICAR program STATS was run for each of the five dates in the data set, using all eight channels of information for each date (MSS4, MSS5, MSS6, MSS7, MSS7/MSS5 ratio, Brightness, Greeness, and Yellowness).

Since it is neither possible (using VICAR) nor desirable to classify using a 40-channel image, a preliminary task was the selection of optimal channels for cotton classification. This task was carried out in two stages: individual divergence analyses comparing the eight channels within each date, and then a final divergence analysis comparing the best channels for all dates. The divergence results showed that the three optimal channels were MSS5, MSS7, and the ratio of MSS7/MSS5. The three optimum dates were May 1 for early season spectral information; October 10 for late season; and July 21 for peak growing season.

5.2 REFINEMENT OF TRAINING CLASSES

A difficulty which often arises in supervised training is high within-site variability. If a training site is overly heterogeneous, means may be biased and the site's dispersion matrix will show higher variances. To detect such a condition, an unsupervised clustering algorithm can be used to classify training site areas; sites showing multiple unsupervised classes can then be omitted as overly heterogeneous. This technique can also be used to identify additional training sites as well as to delineate other spectrally identifiable classes within the scene. These latter applications were the main reason for applying the unsupervised classification techniques used here.

The unsupervised cluster analysis was performed using the VICAR program USTATS on the nine channels of information selected by DIVERG: MSS5, MSS7, and MSS7/MSS5 ratio, for May, July, and October. Sampling each fourth sample in each fourth line, 100 clusters were formed. After removing one-pixel clusters, 97 clusters remained. After combining those clusters which overlapped by one standard deviation, 81 clusters remained. Cluster number 40 was chosen as the "cut-off" for display purposes. VICAR program FASTCLAS was used to classify the nine-channel image using the USTATS file.

The VICAR program DISPLAY then assigned characters to the 40 classes defined by the clusters and produced line-printer output of the classified map. For ease in locating them, the original 13 training fields were scribed on the line-printer map using STATS. VICAR program LIST produced histograms showing frequencies of each of the 40 classes in the training fields for the Coal Oil Canyon (training) quad.

Using the classified output, 37 new training classes of 51 fields, including revisions of the original eight, were defined to more accurately separate cotton from non-cotton based on detailed spectral/temporal characteristics. STATS was run on the 37 training classes using channels MSS5, MSS7, and MSS7/MSS5 ratio for May, July, and October. DIVERG was run using three prespecified combinations of channels:

1. May, July, October: MSS5
2. May, July, October: MSS7
3. May, July, October: MSS7/MSS5 ratio

5.3 SUPERVISED CLASSIFICATIONS

FASTCLAS classified this STATS file twice -- once for the combination of May, July, and October, and once for May only. DISPLAY was used to output four different supervised classifications of these FASTCLAS runs:

1. May, July, October: all 37 classes labeled
2. May, July, October: cotton classes only labeled
3. May: all 37 classes labeled
4. May: cotton classes only labeled

For the May/June and June only classifications, STATS was again run; this time on six channels: May and June, MSS5, MSS7, and MSS7/5 ratio for both dates. FASTCLAS again classified this STATS file twice -- once for the May and June combination, and once for June. DISPLAY was used to output four more supervised classifications:

1. May, June: all 37 classes labeled
2. May, June: cotton classes only labeled
3. June: all 37 classes labeled
4. June: cotton classes only labeled

As with the manual interpretation tests, the above digital classifications were compared for accuracy against the USDA and WR-M WSD "ground truths" for 1976.

6.0 DATA ANALYSIS

On an operational basis, the final product of a crop identification study for the Pink Bollworm Program is a map showing the location of cotton fields with acreage figures to be used to determine trapping districts. However, to determine the accuracy of the manual interpretations and the digital classifications it was necessary to conduct a field-by-field analysis.

6.1 MANUAL

Tables 3-6 through 3-9 show the results of field-by-field comparisons made between manual interpretations by the four interpreters and the ground truth sources for 1974, 1975, 1976, and 1977. The fields which had been eliminated were not included in the total field counts. By examining these tables, variations in the interpretations are evident from year to year, as well as between interpreters and between ground truth sources for the same year. Table 3-10 lists the averages of these interpretations by year and ground truth source.

Table 3-6

Manual Interpretation Accuracies, 1974
Cotton vs. Non-Cotton
Wheeler Ridge-Maricopa Test Site

USDA	Interpreter 1 Cotton	Interpreter 1 Non-Cotton	Total Fields	% Corr
Cotton	209	8 5	217 5	96 1
Non-Cotton	26	106 5	132 5	80 4
Total	235	115	315 5 / 350	90 1

WR-M WSD	Interpreter 1 Cotton	Interpreter 1 Non-Cotton	Total Fields	% Corr
Cotton	206 5	11.5	218	94 7
Non-Cotton	28 5	103 5	132	78 4
Total	235	115	310 / 350	88 6

USDA	Interpreter 2 Cotton	Interpreter 2 Non-Cotton	Total Fields	% Corr
Cotton	195 5	22	217 5	89 9
Non-Cotton	26	106 5	132.5	80.4
Total	221.5	128.5	302 / 350	86 3

WR-M WSD	Interpreter 2 Cotton	Interpreter 2 Non-Cotton	Total Fields	% Corr
Cotton	193 5	24 5	218	88 8
Non-Cotton	28	104	132	78 8
Total	221 5	128 5	297 5 / 350	85 0

USDA	Interpreter 3 Cotton	Interpreter 3 Non-Cotton	Total Fields	% Corr
Cotton	214 5	3	217 5	98 6
Non-Cotton	68	64 5	132 5	48 7
Total	282 5	67 5	279 / 350	79.7

WR-M WSD	Interpreter 3 Cotton	Interpreter 3 Non-Cotton	Total Fields	% Corr
Cotton	213 5	4 5	218	97 9
Non-Cotton	69	63	132	47 7
Total	282 5	67 5	276 5 / 350	79 0

USDA	Interpreter 4 Cotton	Interpreter 4 Non-Cotton	Total Fields	% Corr
Cotton	215	2.5	217 5	98.9
Non-Cotton	32 5	100	132 5	75 5
Total	247 5	102 5	315 / 350	90 0

WR-M WSD	Interpreter 4 Cotton	Interpreter 4 Non-Cotton	Total Fields	% Corr
Cotton	212 5	5 5	218	97 5
Non-Cotton	35	97	132	73 5
Total	247 5	102 5	309 5 / 350	88 4

Table 3-7

Manual Interpretation Accuracies, 1975
Cotton vs. Non-Cotton
Wheeler Ridge-Maricopa Test Site

USDA	Interpreter 1 Cotton	Interpreter 1 Non-Cotton	Total Fields	% Corr
Cotton	126	8	134	94 0
Non-Cotton	80 25	112 75	193	58 4
Total	206 25	120 75	238 75 / 327	73 0

WR-M WSD	Interpreter 1 Cotton	Interpreter 1 Non-Cotton	Total Fields	% Corr
Cotton	126 75	10 5	137 25	92 4
Non-Cotton	79 5	110 25	189 75	58 1
Total	206 25	120.75	237 / 327	72 5

USDA	Interpreter 2 Cotton	Interpreter 2 Non-Cotton	Total Fields	% Corr
Cotton	118	16	134	88 1
Non-Cotton	42.25	150 75	193	78.1
Total	160 25	166 75	268 75 / 327	82 2

WR-M WSD	Interpreter 2 Cotton	Interpreter 2 Non-Cotton	Total Fields	% Corr
Cotton	116 75	20 5	137 25	85.1
Non-Cotton	43.5	146 25	189 75	77 1
Total	160 25	166.75	263 / 327	80.4

USDA	Interpreter 3 Cotton	Interpreter 3 Non-Cotton	Total Fields	% Corr
Cotton	126.5	7 5	134	94 4
Non-Cotton	82.75	110 25	193	57 1
Total	209.25	117 75	236.75 / 327	72.4

WR-M WSD	Interpreter 3 Cotton	Interpreter 3 Non-Cotton	Total Fields	% Corr
Cotton	126 75	10 5	137 25	92.4
Non-Cotton	82 5	107.25	189 75	56.5
Total	209.25	117.75	234 / 327	71.6

USDA	Interpreter 4 Cotton	Interpreter 4 Non-Cotton	Total Fields	% Corr
Cotton	128.5	5 5	134	95 9
Non-Cotton	56	137	193	71 0
Total	184 5	142 5	265 5 / 327	81.2

WR-M WSD	Interpreter 4 Cotton	Interpreter 4 Non-Cotton	Total Fields	% Corr
Cotton	127 25	10	137 25	92.7
Non-Cotton	57.25	132.5	189.75	69.8
Total	184.5	142.5	259.75 / 327	79 4

Table 3-8

Manual Interpretation Accuracies, 1976
Cotton vs. Non-Cotton
Wheeler Ridge-Maricopa Test Site

USDA	Interpreter 1 Cotton	Interpreter 1 Non-Cotton	Total Fields	% Corr
Cotton	189	6 5	195.5	96 7
Non-Cotton	15 5	136	151 5	89 8
Total	204.5	142.5	325 / 347	93.7

WR-M WSD	Interpreter 1 Cotton	Interpreter 1 Non-Cotton	Total Fields	% Corr
Cotton	190.5	11.75	202.25	94.2
Non-Cotton	14	130.75	144.75	90.3
Total	204 5	142.5	321.25 / 347	92.6

USDA	Interpreter 2 Cotton	Interpreter 2 Non-Cotton	Total Fields	% Corr
Cotton	180	15 5	195.5	92.1
Non-Cotton	14	137.5	151.5	90.1
Total	194	153	317 5 / 347	91.5

WR-M WSD	Interpreter 2 Cotton	Interpreter 2 Non-Cotton	Total Fields	% Corr
Cotton	178 75	23.5	202 25	88 4
Non-Cotton	15.25	129.5	144.75	89 5
Total	194	153	308 25 / 347	88.8

USDA	Interpreter 3 Cotton	Interpreter 3 Non-Cotton	Total Fields	% Corr.
Cotton	192	3 5	195 5	98.2
Non-Cotton	38	113 5	151 5	74 9
Total	230	117	305 5 / 347	88 0

WR-M WSD	Interpreter 3 Cotton	Interpreter 3 Non-Cotton	Total Fields	% Corr
Cotton	194	8.25	202.25	95.9
Non-Cotton	36	108.75	144 75	75.1
Total	230	117	30275 / 347	87.3

USDA	Interpreter 4 Cotton	Interpreter 4 Non-Cotton	Total Fields	% Corr.
Cotton	189	6.5	195 5	96.7
Non-Cotton	16 5	135	151.5	89.1
Total	205.5	141.5	324 / 347	93 4

WR-M WSD	Interpreter 4 Cotton	Interpreter 4 Non-Cotton	Total Fields	% Corr
Cotton	189.5	12.75	202 25	93 7
Non-Cotton	16	128 75	144 75	89 0
Total	205.5	141.5	318 25 / 347	91 7

Table 3-9

Manual Interpretation Accuracies, 1977
Cotton vs. Non-Cotton
Wheeler Ridge-Maricopa Test Site

USDA	Interpreter 1 Cotton	Interpreter 1 Non-Cotton	Total Fields	% Corr
Cotton	125 5	4	129 5	96 9
Non-Cotton	118 5	101	219.5	46.0
Total	244	105	226 5 / 349	64 9

WR-M WSD	Interpreter 1 Cotton	Interpreter 1 Non-Cotton	Total Fields	% Corr
Cotton	128 75	14 25	143	90 0
Non-Cotton	115 25	90.75	206	44 0
Total	244	105	219 5 / 349	62 9

DWR	Interpreter 1 Cotton	Interpreter 1 Non-Cotton	Total Fields	% Corr
Cotton	133 5	7 5	141	94 7
Non-Cotton	110 5	97 5	208	46 9
Total	244	105	231 / 349	66.2

USDA	Interpreter 2 Cotton	Interpreter 2 Non-Cotton	Total Fields	% Corr
Cotton	64 25	65 25	129 5	49 6
Non-Cotton	109 75	109 75	219 5	50 0
Total	174	175	174 / 349	49 9

WR-M WSD	Interpreter 2 Cotton	Interpreter 2 Non-Cotton	Total Fields	% Corr
Cotton	64	79	143	44 8
Non-Cotton	110	96	206	46 6
Total	174	175	160 / 349	45 9

DWR	Interpreter 2 Cotton	Interpreter 2 Non-Cotton	Total Fields	% Corr
Cotton	67 5	73 5	141	47 9
Non-Cotton	106 5	101.5	208	48.8
Total	174	175	169 / 349	48 4

USDA	Interpreter 3 Cotton	Interpreter 3 Non-Cotton	Total Fields	% Corr
Cotton	127	2 5	129 5	98 1
Non-Cotton	135	84 5	219 5	38 5
Total	262	87	211 5 / 349	60 6

WR-M WSD	Interpreter 3 Cotton	Interpreter 3 Non-Cotton	Total Fields	% Corr
Cotton	133	10	143	93 0
Non-Cotton	129	77	206	37 4
Total	262	87	210 / 349	60 2

DWR	Interpreter 3 Cotton	Interpreter 3 Non-Cotton	Total Fields	% Corr
Cotton	137.5	3 5	141	97 5
Non-Cotton	124 5	83 5	208	40 1
Total	262	87	221 / 349	63 3

USDA	Interpreter 4 Cotton	Interpreter 4 Non-Cotton	Total Fields	% Corr
Cotton	121 5	8	129 5	93 8
Non-Cotton	129 5	90	219 5	41 0
Total	251	98	211 5 / 349	60 6

WR-M WSD	Interpreter 4 Cotton	Interpreter 4 Non-Cotton	Total Fields	% Corr
Cotton	127 75	15 25	143	89 3
Non-Cotton	123 25	82 75	206	40 2
Total	251	98	210.5 / 349	60.3

DWR	Interpreter 4 Cotton	Interpreter 4 Non-Cotton	Total Fields	% Corr
Cotton	132 5	8 5	141	94 0
Non-Cotton	118 5	89 5	208	43 0
Total	251	98	222 / 349	63 6

Table 3-10
Averaged Overall Interpretation Accuracies

Year	Ground Truth Source USDA	WR-M WSD	DWR
1974	87%	85%	--
1975	77%	76%	--
1976	92%	90%	--
1977	59%	57%	60%

Prior to analyzing the source of variations in interpretation accuracies, it is necessary to know how cotton appears during a "normal" year; in particular, January through May. Based on planting during mid-March to mid-April, cotton is at most 6-8" tall by the end of May (Figure 3-22). During normally warm/hot June, cotton grows rapidly, reaching its peak growth by late July-early August. Cotton is considered a "catch up" crop, and even when planted late is at its peak growth by late July-early August, allowing for normally scheduled defoliation and harvesting practices, fall weather permitting. May is a borderline month for identification; during June, cotton's growth is proceeding more rapidly and less variation is seen in fields planted at different times.

Figure 3-24 is a graph showing early cultivation and growth stages of the San Joaquin Valley cotton crop for January through May, 1974 through 1977, based on data abstracted from "California Crop-Weather" (1).[3] Although each stage of the cycle spans approximately the same length of time, variations are noticeable in the starting dates. The variations in these curves are related to climatological factors, primarily temperature, and also precipitation, which affect the "normal" growth cycle of cotton. Both 1974 and 1976 can be interpreted as "normal" years for cotton. Some late replanting in 1974 was necessary

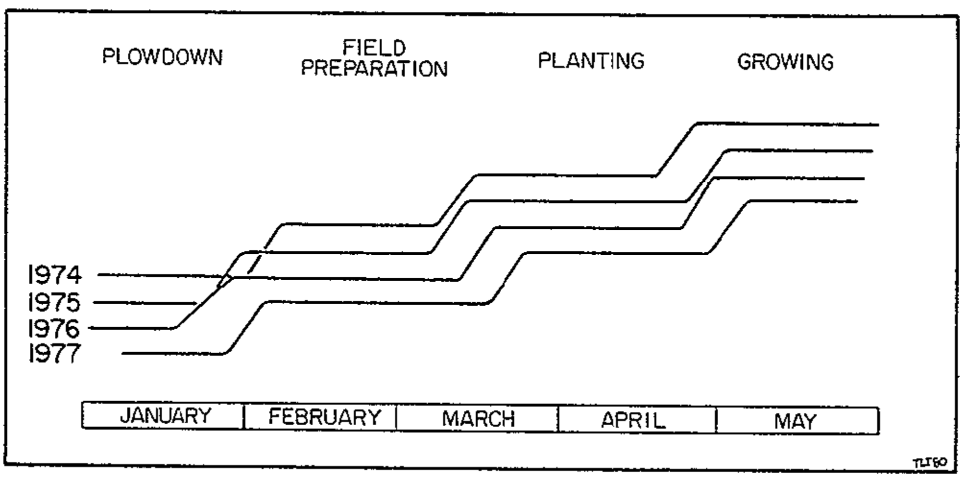

Figure 3-24. Graph showing the variations in starting dates for the early cultivation and growth stages of cotton in the San Joaquin Valley for January-May, 1974-1977. (Information abstracted from "California Crop-Weather".)

as a result of rains in early April, but from there the crop progressed on schedule. Rainfall in early February 1976 caused some delay in field preparation and planting, but, except for some rains in early April which also delayed some planting, there was little delay in the further progression of the 1976 cotton crop. The warmer than normal temperatures in May helped crop growth.

Field preparation and planting for 1975 began on schedule, but cooler than normal temperatures from February through mid-May required late planting and delayed the emergence of cotton. Although 1977 was a drought year, cooler than normal temperatures in January through May had more of an impact on the early stages of the cotton crop. Fields were pre-irrigated where water was available, and planting was on schedule, but early growth during May was slow. These climatic variations are noticeable in Figures 3-25 and 3-26, which show the normal and yearly temperatures and precipitation, respectively, for January through May, 1974, 1975, 1976, and 1977.

The weather affected not only the growth of cotton but the growth of other crops in the region as well. The WR-M Spring Crop Survey was used as "ground truth" for confusion crops for each year. A detailed analysis of the averaged overall interpretations (Table 3-10) as affected by the climatological/phenological factors for the four years of this study follows. Also included are the anticipated results obtainable with the addition of an early June image to identify cotton.

6.1.1 1974

As mentioned previously, January through May of 1974 exhibited "normal" conditions, both for weather and for the cultivation and early growth of the cotton crop. Temperatures were normal, or at most a bit warmer than normal;

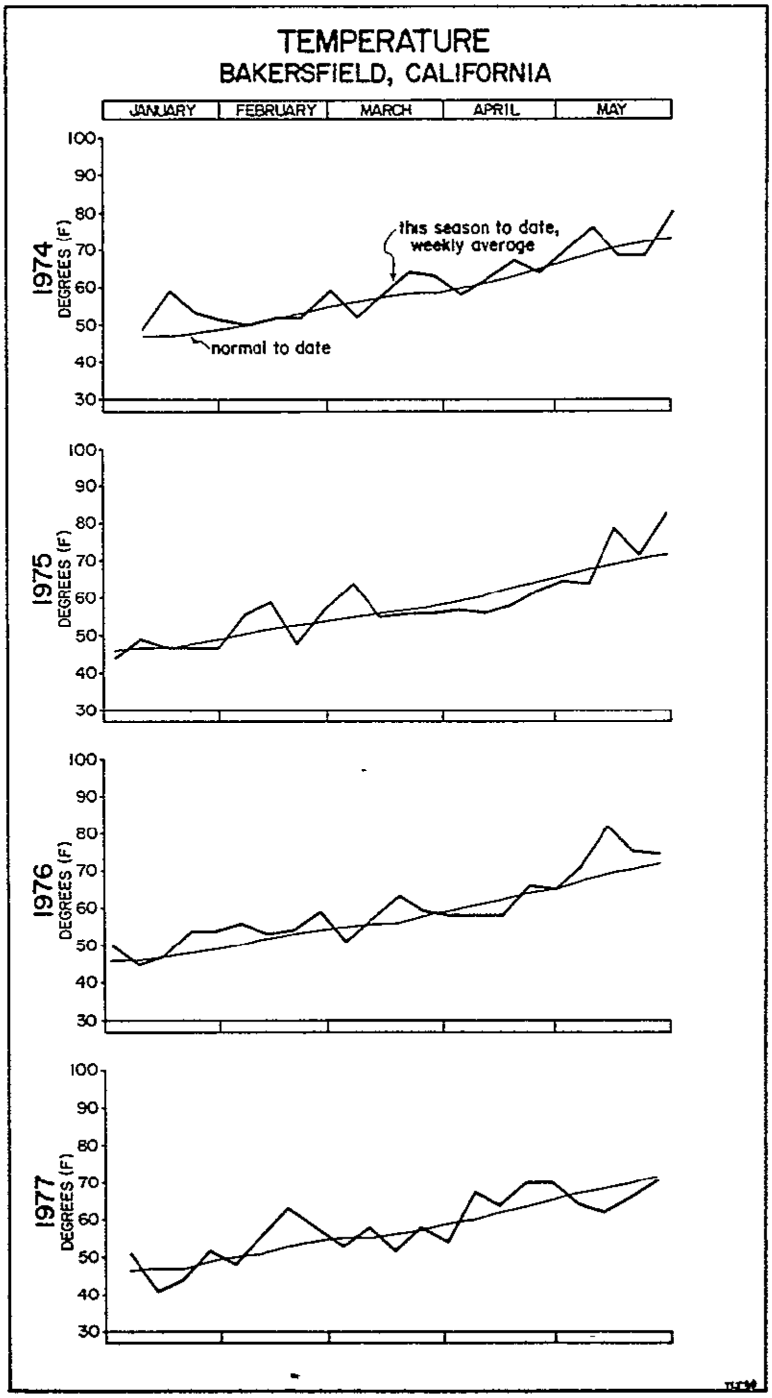

Figure 3-25. Averaged weekly temperatures as recorded at Bakersfield, California, showing normal curve and temperatures experienced for January-May, 1974-1977. (Data source: "California Crop-Weather".)

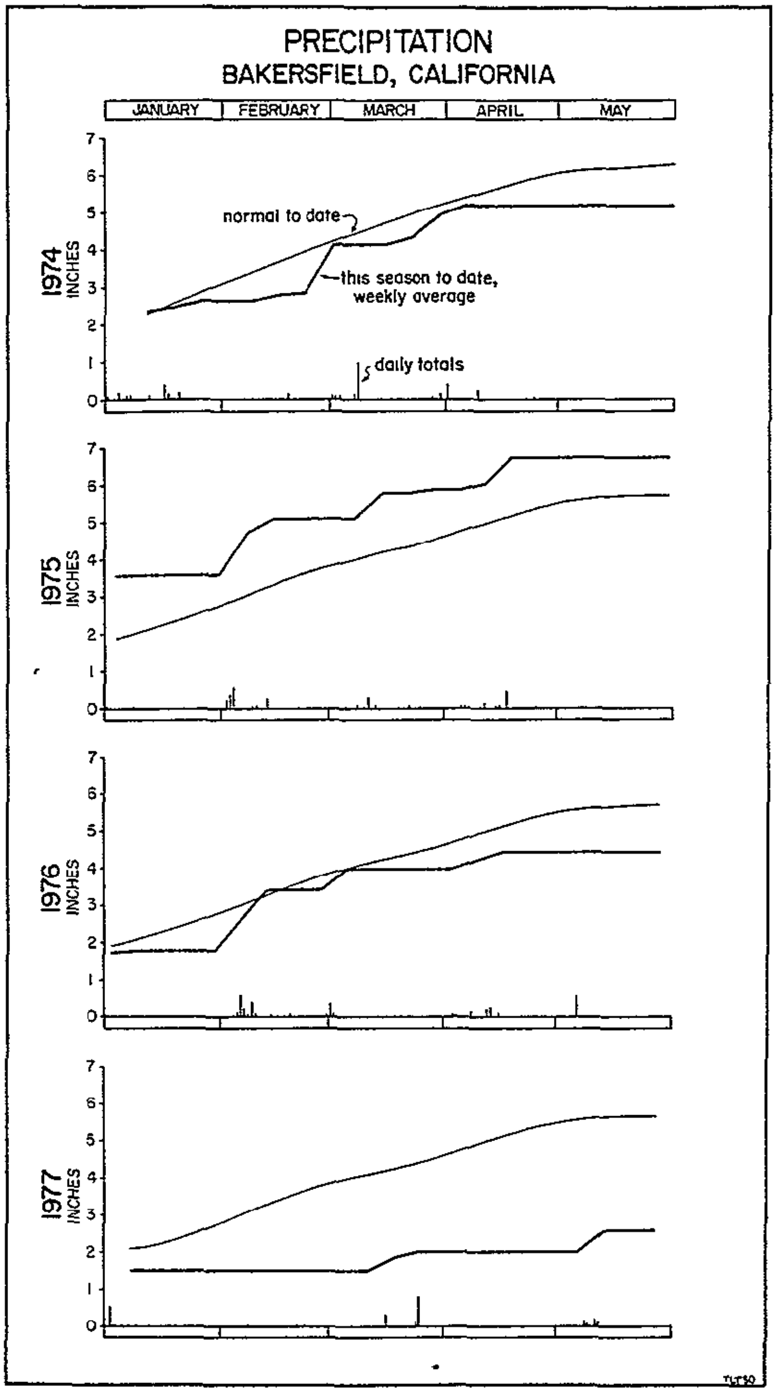

Figure 3-26. Averaged weekly precipitation as recorded at Bakersfield, California, showing normal curve and precipitation experienced for January-May, 1974-1977. (Data source: "California Crop-Weather".) The daily totals for this same time period are also shown. (Data source: "Local Climatological Data".)

precipitation was a bit lower than expected (see Figures 3-25 and 3-26). The planting, emergence, and early growth of cotton were on schedule. Landsat 1 passed over the study area eight times during this early season period, with seven usable scenes. On only one overpass date was the test site region obscured by clouds. May 21 was the latest image that could be used in the interpretations to stay within the Pink Bollworm Program deadlines of late May.

Crops which caused the most confusion for the interpreters were tomatoes and melons, and peppers to a lesser extent. Tomatoes are on the same planting schedule as cotton, with emergence of both crops coinciding. The early season spectral responses of both these crops as imaged by Landsat's MSS are similar. The spectral response of melons is also similar through late May.

The averaged overall accuracies for 1974 were in the upper 80's: 85% (vs. WR-M WSD) and 87% (vs. USDA). The addition of the early June image, June 8, should increase interpretation accuracies by enabling the interpreters to more easily distinguish melons and cotton. Tomatoes, however, would still be expected to cause confusion.

6.1.2 1975

January through early May of 1975 were characterized by colder than normal temperatures (Figure 3-25). Lower ground temperatures caused delays in planting of cotton, and lower temperatures in general caused delays in emergence of the crop. At the end of April the cotton crop appeared "to be 1-2 weeks behind schedule" (1, 4/25/75). Warmer weather the latter half of May helped the growth of the crop.

Usable coverage by Landsats 1 and 2 was poor January-March, but during April and May only one scene was not obtainable. However, the latest date of coverage, May 25, although late in May was not adequate because of the delayed growth of cotton. More so than in 1974, both melons and tomatoes caused much interpreter confusion. As with the delay in planting of cotton due to cool ground temperatures, planting of tomatoes and melons was also delayed. There was also some confusion with fallow fields; this effect can only be explained by fallow appearing similar to the delayed cotton fields.

Delayed planting of not only cotton, melons, and tomatoes, but other crops as well, is probably responsible for the lower interpretation accuracies: 76% (vs. WR-M WSD) and 77% (vs. USDA). Addition of the early June Landsat overpass, June 2, to the interpretation would eliminate the confusion with both melons and tomatoes and help to increase overall cotton versus non-cotton identification accuracies.

6.1.3 1976

As with 1974, 1976 also experienced a "normal" early growing season with respect to scheduled cotton crop development. Temperatures were near normal during this five-month period, with some weeks experiencing cooler weather and other weeks warmer (Figure 3-25). Rains in early April delayed planting and resulted in some replanting (Figure 3-26). Although during early May the cotton crop was "doing well but is late" (1, 5/7/76), warmer than normal weather for the rest of May enabled rapid growth.

Usable Landsat coverage, although sporadic for the five-month period, provided an overpass late in May. The good early growing season, combined with the May 28 scene, seemed to reduce the problem of confusion crops. Identification errors appeared to be sporadic, with no consistent misidentification of any particular crop by all four interpreters. The averaged overall accuracies tend to indicate this: 90% (vs. WR-M WSD) and 92% (vs. USDA). Addition of the following overpass, June 6, probably would not increase interpretation accuracies appreciably.

6.1.4 1977

1977 is remembered as the drought year, but cooler than normal temperatures during May had a greater impact on cotton growth during the early season than lack of water. This cool weather slowed growth of the cotton crop during May, as it did in 1975 (see Figures 3-25 and 3-26).

Coverage by Landsats 1 and 2 was sporadic and poor, especially with respect to May coverage of the test site. During the latest May overpass, May 20, Landsat 1 was experiencing malfunctioning problems with MSS4. The May 20 false color composite was comprised of MSS5 (green filter) and MSS7 (red filter) only, having a major impact on the ability to distinguish crop types. For this reason, the latest effective usable date of coverage was May 14, which, when combined with cotton's slow growth during May, resulted in very low interpretation accuracies: 57% (vs. WR-M WSD), 59% (vs. USDA), and 60% (vs. DWR).

Because of these poor interpretation accuracies, two interpreters took the 1977 interpretation test again with the addition of the early June date, June 1. The interpretation accuracies increased by almost 25% (see Table 3-11), raising the averaged interpretations for these two interpreters to 79% (vs. WR-M WSD), 82% (vs. USDA), and 84% (vs. DWR). Confusion in the interpretations centered primarily around misidentification of fallow fields. Interpreters expected more cotton fields than actually existed because of the drought; and having May 14 as the latest usable image contributed to this error. Misidentification of fallow fields decreased with addition of the June 1 image. Wheat was also frequently misinterpreted, although careful interpretation of the March 3 image should have avoided this confusion. On the May 14 image misidentified wheat fields did look like cotton, although on the June 1 image wheat again was separable from cotton.

Table 3-11

Manual Interpretation Accuracies, 1977
With Addition of Early June Image
Cotton vs. Non-Cotton
Wheeler Ridge-Maricopa Test Site

USDA	Interpreter 1 Cotton	Non-Cotton	Total Fields	% Corr
Cotton	115.75	13.75	129.5	89 4
Non-Cotton	45	174.5	219.5	79.5
Total	160 75	188 25	290 25 / 349	83.2

USDA	Interpreter 2 Cotton	Non-Cotton	Total Fields	% Corr
Cotton	113.5	16	129.5	87.6
Non-Cotton	50 5	169	219.5	77.0
Total	164	185	282.5 / 349	81.0

WR-M WSD	Interpreter 1 Cotton	Non-Cotton	Total Fields	% Corr
Cotton	116.75	26 25	143	81.6
Non-Cotton	44	162	206	78.6
Total	160.75	188 25	278.75 / 349	79.9

WR-M WSD	Interpreter 2 Cotton	Non-Cotton	Total Fields	% Corr
Cotton	114 25	28.75	143	79.9
Non-Cotton	49 75	156.25	206	75.9
Total	164	185	270.5 / 349	77.5

DWR	Interpreter 1 Cotton	Non-Cotton	Total Fields	% Corr
Cotton	124 25	16.75	141	88.1
Non-Cotton	36 5	171 5	208	82.5
Total	160.75	188 25	295.75 / 349	84 7

DWR	Interpreter 2 Cotton	Non-Cotton	Total Fields	% Corr
Cotton	123	18	141	87.2
Non-Cotton	41	167	208	80.3
Total	164	185	290 / 349	83 1

6.1.5 Summary of Manual Analyses

Based on an analysis of the interpretation results discussed above, manual identification of cotton fields for the Pink Bollworm Program can attain by-field identification accuracies in the low 90's. This level of accuracy is comparable to the accuracy seen when "ground truth" sources are compared one against another (see Table 3-4). Figure 3-27 is a graph comparing interpreter and ground truth accuracies for each of the four years of this study. In the 1976 interpretation, specifically, this points out that interpreter accuracy can match, if not exceed, the relative ground truth accuracies.

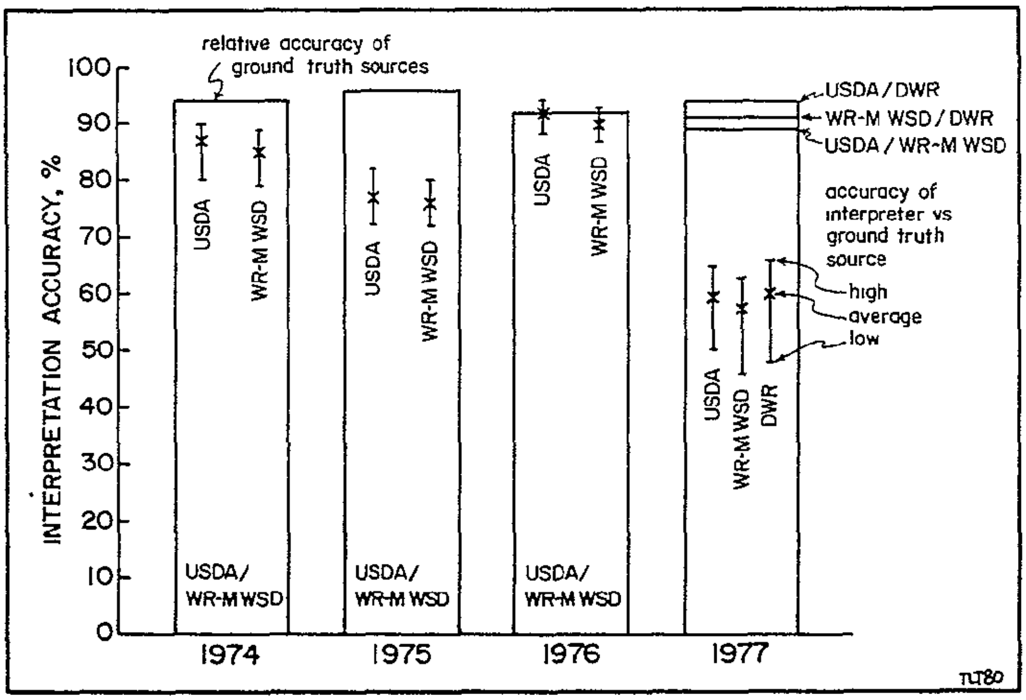

Figure 3-27. Graph comparing interpreter and ground truth accuracies for the four years of this study. The results shown here for 1977 do not include addition of the early June image.

However, to consistently achieve comparable accuracies the January-May time constraint may have to be extended into early June at certain times. This is pointed out in the general conclusions that can be drawn from the 1974, 1975, 1976, and 1977 manual interpretation analyses. Based on this analysis, then, conducted in the Southern San Joaquin Valley, California, the following conclusions appear appropriate:

(1) Delays in the phenological cycle of cotton, in particular planting and emergence, whether due to cooler than normal temperatures or excessive precipitation, will require the additional information contained in an early June Landsat image to bring accuracies up to the low nineties.

(2) The total number of usable Landsat overpasses does not seem to be critical in identification of cotton versus non-cotton; however, the timing of the latest overpass does seem to be critical.

(3) Confusion of cotton with other crops is unavoidable unless very late May or early June dates are used. Melons will usually be separable by this time; however, tomatoes may cause problems until late June.

6.2 DIGITAL

The four digital cotton classifications performed using the 1976 Landsat digital data set were : 1) May 1; 2) June 6; 3) May 1 and June 6; and 4) May 1, July 21, and October 10. The first three meet temporal constraints of the Pink Bollworm Program's cotton mapping requirements if the deadline is extended into early June. The fourth classification is applicable to plowdown monitoring of cotton fields. It is the first three cotton classifications, in particular the May/June cotton classification, that are comparable to manual interpretations for identification of cotton.

Tables 3-12 through 3-15 show the classification accuracies for the four cotton classifications. These accuracies were derived on a field-by-field basis using USDA and WR-M WSD cotton maps as ground truth sources. The fields which had been eliminated in the manual interpretation tests were also eliminated in the tallies of the digital classifications. Although only accuracies for the test site were computed, the entire three-quad area extending beyond the borders of the test site was classified.

As described in the analysis of the manual interpretation accuracies, 1976 is considered a "normal" year for cotton growth. Temperatures were a bit warmer than normal, especially during May (see Figure 3-25), allowing for rapid crop development. Precipitation was a bit less than normal (see Figure 3-26), avoiding the major delays in planting and emergence that accompany heavy rainfall.

Following is a detailed analysis of each of the four digital classifications, including a dicussion of the confusion crops.

6.2.1 May 1, 1976: One-Date Classification

Cotton versus non-cotton classification accuracies for this early May date, as seen in Table 3-12, are 87.2% (vs. WR-M WSD) and 87.5% (vs. USDA). Confusion centered primarily around melons, as well as tomatoes and wheat, being misclassified as cotton. As mentioned above, melons, tomatoes, and cotton are on similar early growing season schedules. During late April-early May, these crops are just emerging and their crop signatures appear similar to the Landsat MSS.

Table 3-12
Digital Classification Accuracies
Landsat MSS5, MSS7, r7/5: May 1976

USDA	Landsat Cotton	Landsat Non-Cotton	Total Fields	% Corr
Cotton	187.5	6	193.5	96.9
Non-Cotton	36.25	107 25	143 5	74.7
Total	223 75	113 25	294.75 / 337	87.5

WR-M WSD	Landsat Cotton	Landsat Non-Cotton	Total Fields	% Corr
Cotton	190	9.25	199 25	95 4
Non-Cotton	33.75	104	137,75	75.5
Total	223.75	113 25	294 / 337	87.2

The reason for the confusion with wheat is not as obvious, since it is on a much different growing cycle than cotton (compare Figures 3-22 and 3-23). However, the early yellowing stage of the wheat crop may appear the same as the early emerging stage of cotton, thereby producing misclassification.

By analyzing the spectral plots (± one standard deviation) from the STATS output for the 37 classes for May and June, channels MSS5, MSS7, and r7/5, it can be determined that the cotton classes are not completely separable on any one of these three channels for May from those classes which comprised the confusion crops. The wheat classes were primarily confused with class 1 cotton, which contained a late planted cotton field. In order to clear up the confusion on this date, another channel that could differentiate between these crops could be incorporated into the classification.

6.2.2 June 6, 1976: One-Date Classification

The overall classification accuracies for cotton versus non-cotton for this date (see Table 3-13) were much lower than for May: 72.6% (vs. WR-M WSD) and 74.0% (vs. USDA). These results may be somewhat surprising since coverage by this June date is further into cotton's growth cycle. There is virtually no confusion with melons and tomatoes; however, there is increased confusion with wheat, as well as lettuce and natural vegetation.

Table 3-13
Digital Classification Accuracies
Landsat MSS5, MSS7, r7/5: June 1976

USDA	Landsat Cotton	Landsat Non-Cotton	Total Fields	% Corr
Cotton	143	50.5	193.5	73.9
Non-Cotton	37	106.5	143.5	74.2
Total	180	157	249.5 / 337	74.0

WR-M WSD	Landsat Cotton	Landsat Non-Cotton	Total Fields	% Corr
Cotton	143.5	55.75	199.25	72.0
Non-Cotton	36.5	101.25	137.75	73.5
Total	180	157	244.75 / 337	72.6

By analyzing the STATS spectral plots for the three June channels, it can be seen that there is no separability between cotton and wheat. The MSS7/MSS5 ratio channel should have been able to separate out some of the lettuce fields from cotton fields. Many fields identified as lettuce by the WR-M WSD Spring Crop Survey were double-cropped with cotton. The lettuce crop has been harvested and cotton crop planted by June. This results in the cotton signature appearing in the June Landsat data.

Lower classification accuracies may be expected on this date. Analyzing the class pair separability for cotton versus non-cotton shows lower average separability of cotton from non-cotton for June than for May.

6.2.3 May 1 and June 6, 1976: Two-Date Classification

Table 3-14 lists the overall classification accuracies of this two-date classification of cotton. The results, 89.0% (vs. WR-M WSD) and 89.8% (vs. USDA), are higher than those of the two one-date classifications just discussed. This classification is most comparable to the manual interpretations, which are only 1-2% higher in overall accuracy than the digital approach.

Table 3-14
Digital Classification Accuracies
Landsat MSS5, MSS7, r7/5: May/June 1976

USDA	Landsat Cotton	Landsat Non-Cotton	Total Fields	% Corr
Cotton	188.5	5	193 5	97.4
Non-Cotton	29.5	114	143.5	79.4
Total	218	119	302.5 / 337	89.8

WR-M WSD	Landsat Cotton	Landsat Non-Cotton	Total Fields	% Corr.
Cotton	190	9.25	199.25	95.3
Non-Cotton	28	109 75	137 75	79.7
Total	218	119	299.75 / 337	89.0

Confusion crops for this classification include wheat, lettuce, and also some melons. Based on analysis of the STATS spectral plots described above, wheat was confused with class 1 cotton (late planted cotton). Confusion with lettuce fields is again due to double-cropping of cotton with lettuce, as described above. The STATS spectral plots were analyzed to explain the misclassification of melons as cotton. They show no separability between the cotton classes and the melon class for any of the six channels.

6.2.4 <u>May 1, July 21, October 10, 1976: Three-Date Classification</u>

This three-date classification, although not within the cotton mapping timelines of the Pink Bollworm Program, shows the accuracies potential of crop type classification given a series of dates over a full growing season's data. As discussed earlier, a classification such as this could be used in the plow-down monitoring stage of the Pink Bollworm Program. Table 3-15 lists the classification accuracies for this cotton classification: 93.4% (vs. WR-M WSD) and 94.4% (vs. USDA). Accuracies using the WR-M WSD ground truth were compared using the Fall Changes made by WR-M WSD on the Spring Crop Survey.

Table 3-15
Digital Classification Accuracies
Landsat MSS5, MSS7, r7/5: May/July/October 1976

USDA	Landsat Cotton	Landsat Non-Cotton	Total Fields	% Corr.
Cotton	190 5	3	193.5	98.4
Non-Cotton	16	127.5	143.5	88 9
Total	206 5	130.5	318 / 337	94 4

WR-M WSD	Landsat Cotton	Landsat Non-Cotton	Total Fields	% Corr
Cotton	195 75	11 5	207.25	94.4
Non-Cotton	10.75	119	129.75	91 7
Total	206.5	130 5	314 75 / 337	93 4

The main crop confusion was with lettuce. Three of these five fields were identified as cotton on the Spring Crop Survey, and identified as lettuce on the Fall Changes. No other crop type caused any major confusion.

6.2.5 Summary of Digital Analyses

Results indicate that digital classification accuracies in the high 80's are possible employing one or two dates of early season data. Although these accuracies are slightly lower than those between the "ground truth" sources, a digital approach such as this may still prove useful. However, as concluded from the manual approach, the January-May time constraint for mapping cotton may have to be extended into early June at certain times, due to the impact of climatological factors on agricultural practices and the phenology of cotton and other crops.

Because this digital data set was "pre-existing," it may not contain optimum dates for identification and classification of cotton. To meet the cotton mapping deadlines, an early May date, such as May 1, seems an appropriate starting date for classification based on cotton's "normal" phenology. A late May or early June date should next be included to meet the Pink Bollworm Program's deadlines. As described in the 1976 manual analysis, it was felt that

May 28 and June 6 contain similar data, the later date not adding an appreciable amount of information. It would therefore be expected that similar classification accuracies would have been obtained using the May 28 date rather than the June 6 date, if available.

The higher classification accuracies attained by the digital approach using three dates for classification would be applicable to the plowdown monitoring aspect of the Pink Bollworm Program. A classification such as this would be less dependent upon optimum dates of coverage than upon general dates of coverage during the early growth, peak growth, and defoliation stages of cotton's growth cycle.

6.3 SUMMARY OF RESULTS

Accuracies attained by both the manual interpretations and the digital classifications are comparable to, although a bit lower than, accuracies of the ground truth sources. Confusion in both approaches centered primarily around melons and tomatoes, which can be expected from the similarity of the early growing season schedules for these crops and cotton. Wheat unexpectedly caused some confusion in the 1977 manual and 1976 digital cotton identifications. This confusion should have been avoided by inclusion of April coverage in the manual interpretation tests, which is when wheat is at its peak stage of growth.

The impact of climatological factors on agricultural practices and phenology of cotton and other crops in the region is important in determining the optimum dates for identification of cotton. If planting and emergence of cotton have not been delayed due to cold ground temperatures or wet fields and are progressing on schedule, an early-May date and a late-May date will be sufficient for identifying cotton. If the cotton crop has been delayed at all, the necessity of the early June coverage becomes apparent, as in the 1977 example. Landsat coverage prior to May serves only to eliminate from further identification those fields which have a winter crop on them. At this time, cotton fields cannot be separated from bare soil. If an eliminated field later becomes double-cropped with cotton in April-May, this field may not be reidentified as containing cotton.

7.0 CONCLUSIONS

This research has demonstrated the feasibility of a Landsat-based methodology for early season manual and digital mapping of cotton fields in the southern San Joaquin Valley, California. Techniques developed herein appear suitable for implementation by state and federal agencies responsible for enforcement of the Pink Bollworm Program given rapid delivery of Landsat data products. However, the time constraint of producing maps showing the location of all cotton fields by early June may have to be extended into mid-June when crop phenology is delayed by cold or wet Spring weather.

Manual multi-date cotton interpretation tests showed that interpretation accuracies are comparable to accuracies obtained by automotive "windshield surveys" currently utilized by those agencies gathering agricultural information in the study area. The digital classifications, although exhibiting identification accuracies a bit lower than the manual approach, show potential as an alternative to manually interpreting Landsat imagery. In general, accuracies achieved by both approaches appear sufficient to supplement, if not replace, present ground-based methods for mapping cotton.

The phenology of cotton as affected by climatological factors -- most importantly, temperature and precipitation -- must be taken into account when determining the deadline for a Landsat-based cotton inventory. This research has shown the importance of including an early June image if the crop is at all behind schedule.

Depending upon location a variety of crops could be confused with cotton. In the Kern County test site, these crops were primarily melons and tomatoes, which have early growing season phenologies similar to cotton. Wheat also unexpectedly caused misidentification problems in the 1977 manual and 1976 digital approaches. Based on an analysis of the wheat phenology this crop should be quite separable from cotton, and perhaps refinement of training data for both manual and digital approaches may clear this confusion.

Based on the digital classification, it appears that a minimum of two Landsat overpasses will give good identification results. These two overpasses should be acquired during late April-early May and late May-early June. The probability of obtaining two frames of usable data in this time frame is .86, based on two functioning Landsat satellites in their present 18-day orbit configurations (6).

To fully implement a project such as developed in this research on an operational scale, additional research, a committment from users, and timely data acquisition are needed. Additional research applying the techniques developed here to other test sites throughout the cotton growing region of the San Joaquin Valley will enable more accurate evaluation of these techniques for an early season cotton inventory. If proven either equal or more cost-efficient than present "windshield surveys," a committment from users (such as CDFA and USDA) to incorporate these techniques into their current Pink Bollworm Program should be obtainable. It is hoped that, with a demand for timely data acquisition, an immediate turnaround of Landsat data will not be an impossibility.

The importance of cotton in both the state and the national economy will probably remain high. The need for pest control for such a valuable crop will also continue. Procedures using remote sensing techniques such as the one developed in this thesis for the Pink Bollworm Program will enable agencies such as USDA and CDFA to more efficiently pursue their program for pest control.

Footnotes

[1]Orchards and vineyards do not appear in Table 1 because they have been eliminated from the interpretations and classifications.

[2]The three-date classification, if accurate, could be used in the plowdown monitoring stage of the Pink Bollworm Program. The state and federal regulations require "plowdown" of all cotton refuse early in the year (for the previous year's crop). By knowing the location of all cotton fields, it would be possible to determine by later Landsat coverage, or field survey, if all cotton fields were in compliance with the plowdown regulations by the specified date.

[3]"California Crop-Weather" is a weekly bulletin distributed by the California Crop and Livestock Reporting Service. It contains a short synopsis of the past week's weather throughout the agricultural regions of the state. The current progress of a number of field, fruit and nut, and vegetable crops, as well as livestock, is briefly described. Averaged temperatures and total precipitation by California Stations for the week are also included.

REFERENCES

1. California Crop and Livestock Reporting Service, 1974-79, "California Crop Weather."

2. California Department of Food and Agriculture, 1978, "Pink Bollworm Program in the San Joaquin Valley of California -- A Position Paper," 7pp.

3. Cotton Pest Control Advisory Board, n.d., "California's Pink Bollworm Program," pamphlet.

4. Donley, M. W., et al., 1979, Atlas of California, Pacific Book Center, Culver City, California, p. 132.

5. Durrenburger, R. W. and R. B. Johnson, 1975, California: Patterns on the Land, Mayfield Publishing Company, Palo Alto, California, p. 82.

6. Estes, J. E., et al., 1976, "Water Demand Studies in Central California," chapter 3 in An Integrated Study of Earth Resources in the State of California Using Remote Sensing Techniques, Space Sciences Laboratory, University of California, Berkeley, 83pp.

7. Jet Propulsion Laboratory, various dates, VICAR Manual, unpublished program documentation, available at GRSU, UCSB.

8. Kauth, R. J. and G. S. Thomas, 1976, "The Tasselled Cap -- A Graphic Description of the Spectral-Temporal Development of Agricultural Crops as Seen by Landsat," 1976 Symposium on Machine Processing of Remotely Sensed Data, LARS, Purdue University, West Lafayette, Indiana, p. 4B-41-4B

9. Lambeck, P. F., 1977, "Signature Extension Preprocessing for Landsat MSS Data," Final Report, Report #NASA CR-ERIM 122700-32-F, ERIM, Ann Arbor, Michigan, 85 pp.

10. National Aeronautics and Space Administration, 1976, Landsat Data Users Handbook, Goddard Space Flight Center, Greenbelt, Maryland, Document No. 76SDS4258.

11. National Oceanic and Atmospheric Administration, 1975-1977, "Local Climatological Data: Monthly Summary," National Weather Service Office, Kern County Air Terminal, Bakersfield, California.

12. Torburn, T. L., 1980, "Identification of Cotton Fields from Landsat Imagery in the Southern San Joaquin Valley, California," Master's thesis, Univeristy of California, Santa Barbara, 118 pp.

13. Watkins, A. H., 1978, The EROS Data Center, United States Government Printing Office, Washington, D.C., 37 pp.

CHAPTER 4

SOUTHERN CALIFORNIA STUDIES

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May 1, 1980

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CHAPTER 4

APPLICATION OF REMOTE SENSING TO SELECTED PROBLEMS IN SOUTHERN CALIFORNIA - THE AVOCADO INDUSTRY

4 .0 INTRODUCTION

4.0.1 SUMMARY

The unprecedented increase in avocado acreage in California during the past eight years has created a nearly impossible crop forecasting problem for the California Avocado Commission. Acreage has increased from 25,896 acres in 1972 to over 55,000 acres in 1980. No agency has been able to keep an accurate inventory. The hilly terrain, sparse road networks and prohibition of travel from field to field (to prevent transmission of root rot disease) have made inventories by conventional methods most difficult and in some areas nearly impossible. The California Avocado Commission and the University of California Agricultural Experiment Station are matching funds with NASA in order to support this three-year research project, which is now nearing the completion of the second year. The California Livestock and Crop Reporting Service, which will be a primary beneficiary from the resulting techniques is also assisting the project. The purpose of the project is to develop remote sensing methods that will provide up-to-date and accurate data from which the avocado crop forecast can be made. The project proposes the use of multi-stage imagery over a 5 year cycle. LANDSAT satellite imagery is expected to be used perhaps four times per year to provide early detection of new planting activities such as was possible for the Rancho California area in 1972. NASA U-2 or comparable high altitude imagery is planned to be used in intercensal years to verify additions and deletions that are detected (or reported) by various means. Low altitude (approximately 1:12,000) aerial survey photos using color and color infrared film are being utilized to establish the base inventory of the total acreage within the state. It appears that the results of the study will indicate that a total survey need be undertaken no more frequently than every five years. It is anticipated that the major work in San Diego County will be completed by June 30, 1980. Beginning July, 1980, the other eight counties in the state with avocado acreage will be inventoried. The target date for completion of the initial inventory is June 1981.

In association with the Avocado Production Potential study an investigation is being conducted to determine the feasibility of spatial mapping of frost prone areas within an agricultural region. If successful the mapping project will enable the potential avocado growing areas to be delineated and thus reduce the cost and effort required to identify new avocado development within the state. The study is utilizing the Daedalus Multi-spectral Scanner (DMS) thermal infrared channels on the NASA U-2 aircraft. The techniques developed by this study can then be utilized with Thermal Infrared data derived from LANDSAT D when it is launched.

4.0.2 STUDY AREA

The major avocado growing areas occur in eight southern coastal counties of California (San Diego, Riverside, Orange, Los Angeles, Ventura, Santa Barbara, and San Luis Obispo) and Tulare County in the central valley. The project to date has focused on the plateaus from Escondido north to Fallbrook in San Diego County. The study is now progessing northward to the West Mesa of Rancho California in Riverside County. Figure 1 is a February 1979 LANDSAT Image of the San Diego-Riverside Counties avocado areas. The overlay outlines the specific avocado-growing regions under study.

The typical landscape of each of these sub-areas consists of rolling hills within small highland (or plateau) valleys. The geomorphological settings permit the climate to be affected by the modifying influence of the coastal weather from the Pacific Ocean 10 to 20 miles to the west. The coastal influence results in the moderation of the summer temperatures and a reduction of the extreme effects of the more severe winter cold waves. Killing frosts are rare although temperatures will dip in the low 20's (degrees Fahrenheit) on two or three nights during the winter.

4.1 THE PROBLEMS

Two basic needs are being addressed by this project: The California Avocado Commission's need for accurate production estimates (which prompted the study) and the need for the development of a workable methodological approach to the creation of an Avocado Production Potential Information System.

The enormous increase in avocado production acreage over the past eight years has created what is presently the avocado industry's major problem.

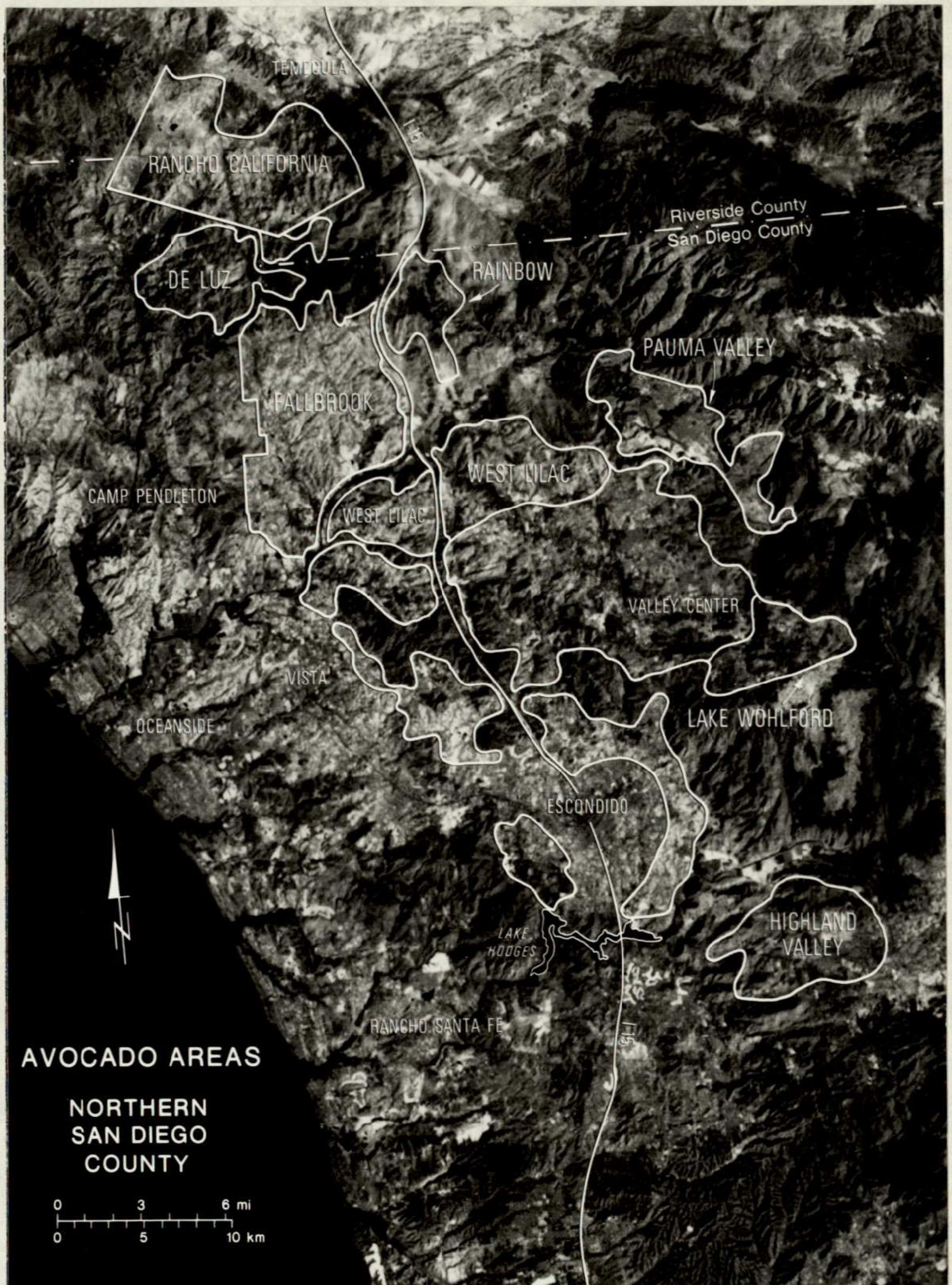

Figure 4-1. Superimposed on a LANDSAT 3 image (Band 7 taken February 28, 1979 centered on Oceanside, California Row 37 path 43) are the various avocado growing areas of northern San Diego County. The areas are of temperate climate either on upland plateaus, highland valleys, or slopes of inland valleys.

Nothing approaching an accurate avocado inventory currently exists. This is because the California Livestock and Crop Reporting Service (CRS) and other state and local governmental agencies have in the past employed inventory methods that are simply not adequate to the task of monitoring the rapid conversion of previously undeveloped land and other types of land uses to agriculture. Even at this stage of the study, several of the difficulties inherent in the methods traditionally employed have been discovered.

4.1.1 THE CALIFORNIA AVOCADO COMMISSION'S PROBLEM

The immediate resource management problem facing the Commission is the generation of accurate periodic production forecasts. This in turn requires the identification of a cost-effective method for establishing and maintaining a current inventory of avocado production. The Commisssion is also faced with a long-term management problem: what steps, if any, should be taken to control the production and marketing of California avocados?

These problems are crucial to the Commission because the legislatively-mandated purpose for its existence is to establish markets for the fruit and to provide an even flow of fruit to those markets. The situation in 1979 illustrates the urgency of the problem. Based on the "gut" feelings of industry packers, it was forecast that 314 million pounds of avocados would be harvested in 1979. Final production figures showed only 246 million pounds were delivered to the market. This meant that several new mid-western, Canadian, and Japanese markets that had been established through heavy advertising based on the high projection received few or no avocados. The 1980 forecast of 145 million pounds is similarly speculative. An industry cannot continue to operate successfully under such conditions. The Commission recognizes that a much more accurate inventory together with some semblance of logical forecasting is vitally needed.

4.1.2 THE PROBLEM OF ESTABLISHING THE INITIAL BASE INVENTORY

When the project was begun, it was believed that the existing inventory of the Crop Reporting Service could be utilized as the initial data base. It was soon discovered that the 1975 CRS crop inventory in San Diego County consisted of a spot check of new avocado plantings based on reports from packing house managers and nurserymen. A ten percent sample was made for avocado groves known to have existed at the time of the last complete survey in 1972. Based upon this sample the total inventory count was modified, but no changes were made in the individual parcel inventory records. Since 1972 there have been so many ownership changes, removals, replantings, and new plantings that the CRS data is only useful for identifying parcels that once contained avocados. Consequently, it has been necessary to conduct a complete new inventory as a basis for the information system.

It has become increasingly apparent that conventional ground surveys are impractical if not impossible in San Diego County. Early field checking revealed that many of the new plantings were in areas that are virtually inaccessible to enumerators. Figure 2 shows a typical area on the plateau north of Valley Center where the road network is extremely sparse. Hard-surface roads bound the area on the north, south, and east. Only dirt roads provide any access to the interior of the area. Many of these roads are private and are quite often secured by locked gates. A major reason for the restriction of access is to prevent the transmission of root rot disease by persons traveling from grove to grove.

The access restrictions and the enormity of the survey strongly suggest that remote sensing is the only feasible method of establishing and maintaining a current inventory.

4.2 OBJECTIVES

The objective of this research project is to develop an Avocado Production Potential Information System (APPIS) that can be updated annually at a minimum of effort and cost.

4.2.1 RESEARCH PLAN

When the avocado project began in 1978 a five phase research plan was outlined. It now appears that the plan will encompass a three year period. Current activity is in the second year. The first year's work completed the first phase, (the feasibility study), and we are presently carrying out phases II and III. The five phases of the research plan are:

Phase 1. Feasibility Study. Perform a pilot study project in a limited area to determine if the project is feasible within acceptable economic limits. The feasibility study will be directed toward determining the best mix of imagery (low-altitude, high-altitude, and satellite) to provide accurate annual avocado production information.

Phase II. Design an Information System. This phase is to design and develop an Avocado Production Potential Information System (APPIS) that will incorporate data from remotely sensed imagery, public records, commission growers surveys, and industry packing house records. The intent of the

Figure 4-2. A 1:24,000 scale photo of the plateau area northwest of Valley Center in northern San Diego County, California. The photo depicts a typical inaccessible area of newly planted avocado acreage. Hard surfaced roads bound the area on the north, south, and east, but only private restricted travel roads bisect the interior region. Inventory by ground inspection is extremely difficult and costly. Furthermore, many owners forbid ground inspector crews to enter their orchards on the grounds that to do so would result in those orchards being infested with the root rot fungus, carried there on the shoes of the crew members and/or on the tires of their vehicles.

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information system is to provide statistical data that will enable a forecast to be made at any time. The information would include the number of acres of avocado land, the number of trees by variety, and the bearing status (life) of the trees.

Phase III. Implementation of the Pilot System. To test the design of the information system, it will be applied with the data produced from the San Diego County inventory. Changes will be made to the system as indicated during this testing phase.

Phase IV. Development of a Statewide System. Upon the completion of the first three phases a statewide system will be developed.

Phase V. Statewide Implementation of the System. At this stage of the research the system will have reached a point of development that will enable the system to be turned over to the California Avocado Commission and/or the California Livestock and Crop Reporting Service to be used in the crop forecasting procedures.

4.2.2. CURRENT OBJECTIVES

The objectives of the avocado study for FY 79-80 encompasses phases II and III of the research plan. The current objectives are:

a. Map all the avocado groves in northern San Diego and Riverside Counties.

b. Provide the number of acres of avocados in the above areas by variety and age.

c. Estimate the accuracy of the data interpreted from various image scales.

d. Produce an estimate of the cost to perform an inventory of all of southern California and a recommendation as to how often a 100% total population survey should be conducted.

e. Establish a basic attribute file for the Avocado Production Potential Information System (APPIS).

4.3 CURRENT AVOCADO INVENTORY RESEARCH STUDIES

The current avocado research efforts are concentrated in two areas of studies: 1) the development of mapping techniques and the gathering of ancillary data for the avocado information system, and 2) the selection and interpretation of imagery. Discussion of these two activities follows.

4.3.1 THE DEVELOPMENT OF MAPPING TECHNIQUES AND GATHERING OF ANCILLARY DATA

Establishing a data base involves the developing of a mapping system as well as transfering the image data or information to the base map. The information system also requires the gathering of ancillary (non-map) data which is compiled from various public records, grower information, and other available data sources. As previously indicated in section 4.1.2 the development of the data base will require a data-gathering approach completely different from that used by the Crop Reporting Service.

4.3.1.1 Mapping Techniques

The most basic consideration of the mapping problem is the development of a system that can be updated periodically by the simplest method. Using this criterion, consideration must be given to: 1) the selection of the basic mapping unit, i.e. the smallest geographical area to be represented, 2) a universal system of numbering the basic mappping units so that all users of the system may locate units geographically without ambiguity, 3) the delimiting of the number of mapping units to be considered at present, but with a provision for additional units in the future, and 4) the selection of a logical mapping area for the aggregation of the individual mapping units.

1) Selection of the Basic Mapping Unit

Avocado groves are developed in various patterns and on many kinds of terrain. Initial consideration of a mapping unit suggested the use of the developed grove. It was soon discovered that ancillary data were difficult to match to the grove-unit concept. Among other things, future sale of portions of the grove unit creates problems in the updating techniques. The other basic unit considered was the tax assessor's parcel. All real property transactions, ancillary data, and unit delineation can be related to the tax parcel. The only difficulty of using the tax parcel as the basic unit concerns the aggregation of parcels into one grove. Quite often the developer using aggregated parcels will plant the grove over the invisible parcel boundary. This prevents detection of the boundary on the imagery. Despite this one disadvantage the tax parcel has been selected as being the most advantageous basic mapping unit for this project.

2) A Universal Numbering System

Previous inventory systems have suffered from the lack of a universal identification system that would locate an avocado grove at an unambiguous geographic location. Since the tax assessor parcel has been selected as the basic mapping unit it appears most logical to accept the tax assessor's parcel code as the parcel identifier. The assessor's parcel code is perhaps the most universal parcel identifier system in use today. All records are changed by this code, the assessor provides maps related to the parcel code, and the maps are available publicly at a nominal price. In many counties in California the assessor's rolls and maps are available on microfiche files. The assessor aggregates parcels into map pages and map books, providing a hierarchial system.

3) The Delimiting of Number of Mapping Units to be Displayed

In selecting the assessor's tax parcel as the basic mapping unit it was determined that it was neither logical nor practical to map all parcels. One possibility was to map only those parcels which contained avocado groves. However, this approach is not necessarily consistent with the primary consideration of rapid updating capability. Avocado production, is expanding into land that lacked previous development. In some instances existing agricultural lands (e.g. citrus crops) are being converted to avocado acreage. A compromise was reached by which all assessor's page boundaries would be mapped. The parcels within these pages that contained avocados and the parcels which had a high potential of becoming avocado groves would be mapped. This decision eliminates all urban areas, which have virtually no possibility of being converted to avocado groves. Some potential undeveloped areas may not be mapped until there is an indication of subdivision into smaller units capable of being planted to avocados. On the average there appear to be approximately 60 parcels per tax assessor's page. In high-density avocado areas such as Fallbrook, California there may be as many as 50% of the parcels containing avocados. In less urban areas there are as little as 10% avocado parcels in the area represented by a page in the assessor's maps. Selective mapping should reduce the total parcels mapped by at least two-thirds.

4) Selection of Logical Areas for Aggregation of Mapping Units

The physical constraints of map displays require that some limit be placed on the size of aggregation of parcels, yet the aggregation can not be so extensive that the scale of the map reduces the parcel scale to an indistinguishable "blob". Experimentation indicates that the tax assessor's aggregation of parcels by pages into a book represents an appropriate display size at the image scale of 1:12,000. The region defined by an assessor's book has been chosen as a logical aggregation unit. The principle of rapid updating suffers to some extent, but these problems are not insurmountable. It is quite possible that several of the book-size mapping areas will be mosaiced into a regional map that possesses relatively homogeneous environmental characteristics. Avocado production could be modeled to include the environmental factors as criteria of production within these larger units.

4.3.1.2 The Gathering of Ancillary Data

One of the principal aims of the image interpretation and mapping components of this project is the creation of a list of assessor's parcel numbers of those parcels containing avocado groves. Once this task has been accomplished, there is a considerable amount of parcel-specific data that can be collected to enhance the usefulness of the system. The data base that is being established will initially contain two groups of information: 1) crop data, and 2) owner/address data. As the requirements of the project dictate, other attributes such as physical site characteristics may be added.

An important first step in establishing the crop inventory is finding the total avocado acreage, aggregated by various units. This is calculated by multiplying the assessor's acres for each parcel by the percentage of the parcel containing avocado trees (based on the interpretation of low-altitude imagery). The parcel values may then be aggregated at the desired reporting level. In addition to acreage, it is anticipated that the number, variety, and age of each subunit or block of avocado trees within each parcel will be collected. This data will be extracted from a mail survey conducted under the auspices of the Avocado Commission. The mailing list for this survey will be composed from the assessor's parcel ownership information.

Owner/address data for avocado parcels are being gathered from assessor's records. The data items include: owner's name, owner's mailing address, parcel site's location address, and ownership type. It is expected that the owner data will be merged into a master list with duplicate entries removed. The commission will assume complete responsibility for this list once it has been produced.

4.3.2 SELECTION AND INTERPRETATION OF IMAGERY

4.3.2.1 Image Acquisition Approach

Multi-stage Imagery

Previous reports have described our research approach as requiring multi-stage imagery for a complete inventory and periodic updating system. The parcel sizes being encountered in San Diego County confirm the need for low-altitude imagery. The average parcel size in San Diego County is less than 5 acres! Producing parcels of less than one-half acre have been discovered.

Because of the great number of small parcels in San Diego County it is necessary to use imagery with sufficient ground resolution to detect the existence of avocado trees (as opposed to citrus or ornamental trees) on the small parcels. Once these small parcels are identified as possessing avocados, it should not be necessary to perform a close inspection of them for at least another five years. In the intervening years a cursory inspection with small-scale imagery can be performed to verify the continued existence of the trees.

In the West Mesa area of Rancho California in southwestern Riverside County the parcels average approximately 20 acres each. The 10,000 acres either planted or being prepared for planting are almost exclusively planted to avocados. Therefore, the imagery scale will normally not need to be any grater than that obtainable from high-altitude platforms such as the U-2. It is believed that with image processing of satellite data it will be possible to monitor an area like Rancho California from LANDSAT in the intercensal years.

Multi-date Imagery

In examining new areas of development like Rancho California it was discovered that the historical files of high-altitude imagery enabled the determination of the year of planting for each parcel (figure 3). It was also possible to monitor the growth of Rancho California avocado production from sequential LANDSAT imagery (figure 4). As the investigation extends into the northern counties of Santa Barbara and Ventura the parcel sizes will increase to as much as 40 acres. Evidence gathered to date suggests that we may be able to both detect and date the plantings from high-altitude and satellite imagery.

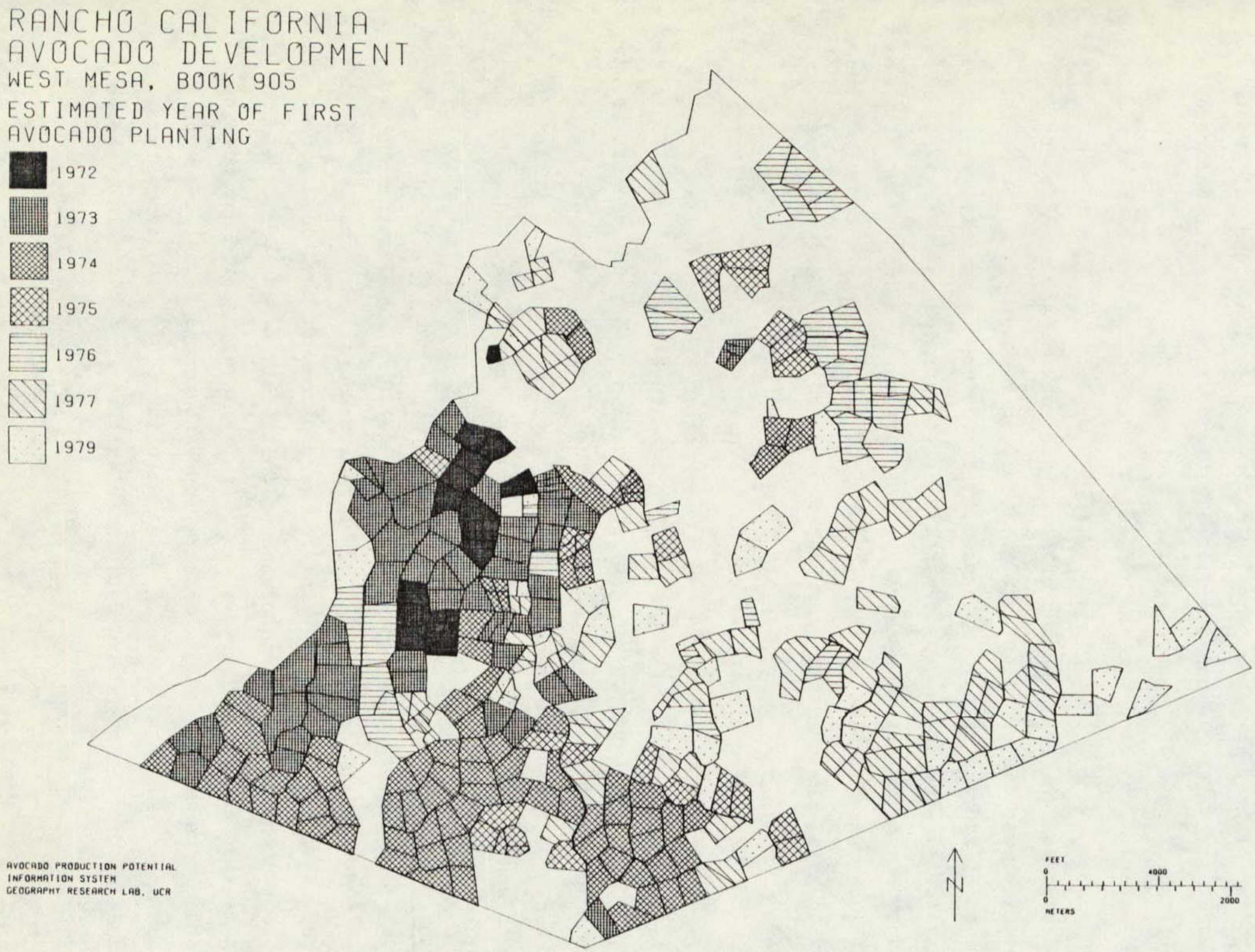

Figure 4-3. Computer shaded map of west mesa area of Rancho California in southwest Riverside County, California. The map indicates the age (year of planting) of each avocado parcel. The information was derived from reviewing historical high-altitude (NASA U-2) imagery dating back to 1972.

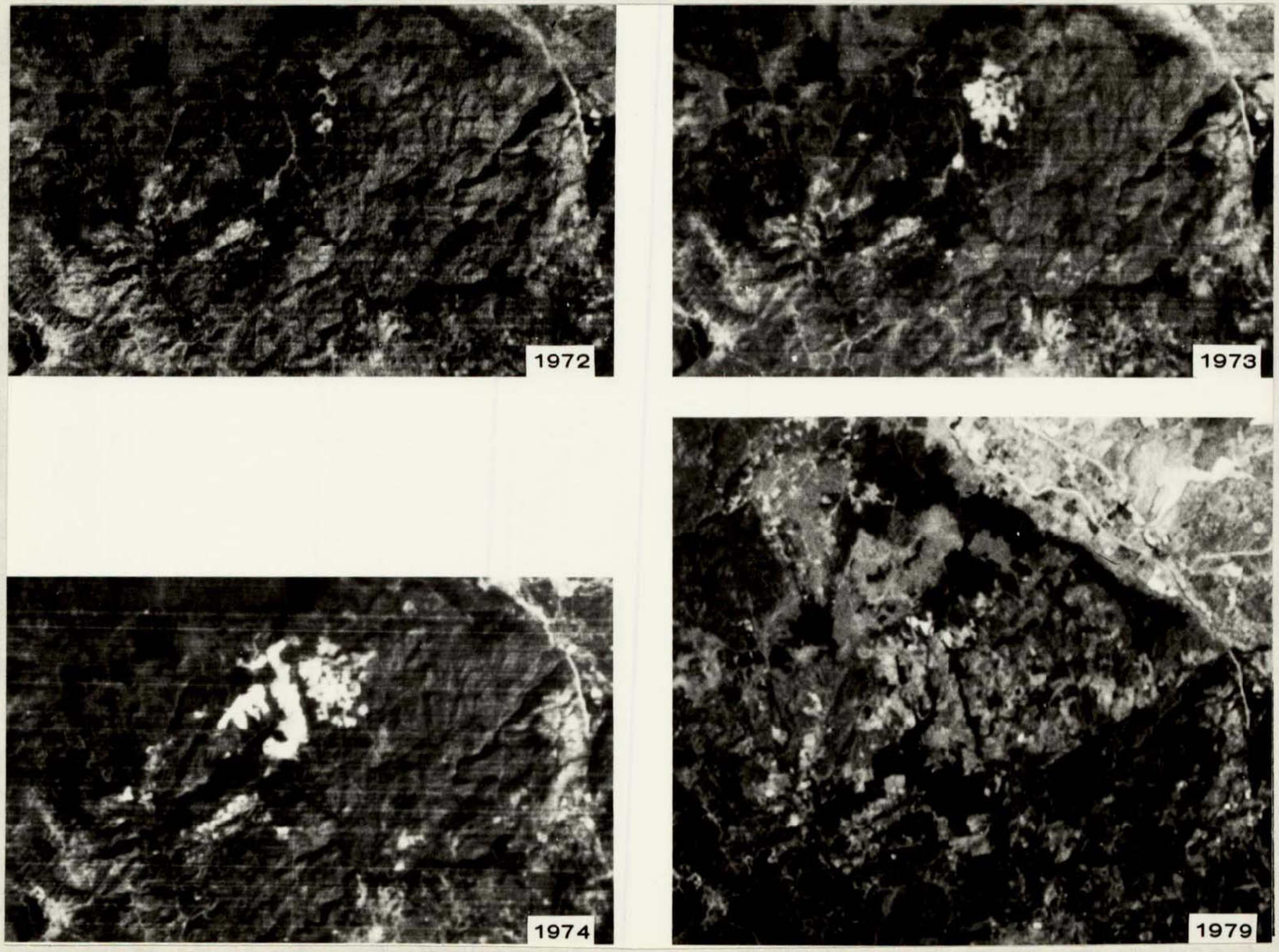

Figure 4-4. Sequence of LANDSAT images monitoring the conversion of undeveloped land to avocados. Cleared and planted acreages are: 1972-100 acres; '73-900 acres; '74-2,600 acres; '79-10,000 acres. The area is the west mesa of Rancho California in southwest Riverside County, California. In general, the lightest toned areas are those recently cleared for the planting of avocado trees, and the darkest areas are mature avocado orchards.

Multi-color Imagery

When studying vegetation, as we are doing, the natural inclination is to use color infra red (CIR) imagry. The initial expriments were with CIR film, but it was soon found that other surrogates (e.g. texture and pattern) had to be used to differentiate avocado trees from citrus trees. From experimentation with ground photographs and by visual inspection it was decided that the difference in the natural green colors between the two fruit trees was distinctive. The next flights were flown with Kodak Aerial Ektagraphic (2448) natural color film and it was indeed discovered that natural color film was more useful in detecting avocado trees than was CIR film. Avocado trees possess a very dark green, uneven texture, and are planted in a rectangular pattern. Citrus trees have a very distinctive lighter shade of green reflection (limes appear to be almost chartreus) with very rounded shapes. Citrus is closely planted, spaced in rows twice as far apart as avocados. The denseness of the color film itself is a disadvantage, but the color differentiation capabilities offset this minor drawback.

4.3.2.2 Evaluation of LANDSAT Imagery for the Detection of Avocado Acreage

The multi-stage approach being developed for this study envisions the use of satellite level imagery to provide early detection of the conversion of undeveloped lands to agricultural uses. Our current investigations into LANDSAT imagery suggests that it may be used in combination with other imagery (e.g. U-2) in order to provide more detail than originally expected. However, some changes in processing of the LANDSAT film data may concern at least some users. The following evaluations sugggest that individual users of new LANDSAT imagery will have to perform their own image processing from Computer Compatable Tapes (CCT's) to obtain the maximum information from LANDSAT data.

The area of our study in northern San Diego County is imaged by the LANDSAT scene centered over Oceanside, California (Path 43, Row 37). We have available a series of these scenes ranging in date from 1972 to 1974. Additionally a July 1975 scene of the area prepared by the EROS Digital Image Enhancement System (EDIES) and two scenes taken in February and July 1979 prepared by the EROS Digital Image Processing System (EDIPS) were obtained. The enhanced images were employed to update information derived from earlier images. At the same time the products were evaluated to determine what, if any, advantages they possessed over the standard images for the type of applications under study.

When the standard LANDSAT MSS scenes were combined on an I^2S additive color viewer, the signatures of crops could be distinguished from urban and chaparral vegetation responses in band 7. Seasonal field crops were excluded with multi-date imagery. The remaining cultivated vegetation areas were isolated as crops. In northern San Diego County the existing tree crops are either avocado trees or citrus trees. Because the same environmental characteristics are conducive to the growth of both avocado and citrus trees, they are found adjacent to one another throughout southern California. To date it has not been possible to discover seasonal signature variations or some other characteristic that would provide discrimination on LANDSAT imagery between the two tree crops. Therefore, LANDSAT imagery may be used to delimit regions labeled as avocado/citrus groves. Higher resolution imagery will be needed to distinguish between these two crops.

Greater success has been achieved in utilizing LANDSAT imagery for the detection of areas being prepared for tree crop planting. Sequential LANDSAT band 5 frames dating from 1972 to the present have shown a remarkable amount of land conversion occuring in Rancho California, a 100,000 acre land development in southwestern Riverside County. One underlying purpose of this development is to establish a mixture of residential development and agricultural production. The degree to which preperty owners have been converting chaparral zones to avocado groves is illustrated in the sequence of LANDSAT subscenes of figure 4. Delineation of these recently cleared lands is fundamental to the problem of estimating the future production potential of the avocado industry. New LANDSAT scenes will be instrumental in monitoring further land conversion.

In conjunction with the identification of avocado production acreage from standard MSS imagery, an effort was made to assess the utility of the EDIES and EDIPS enhanced products. The digital manipulation of the data by EDIES yielded a superior 9x9 inch transparency in all MSS bands when compared to the standard LANDSAT product. The spectral characteristics of tree crops and the bare ground were similar to those shown by the standard product. However, the synthetic line generation, destripping, and contrast and edge enhancement resulted in a less noisy image. The EDIPS products, though anticipated as an improvement over EDIES, did not appear to demonstrate any noticeable superiority. Except for scan line removal, the 9x9 EDIPS MSS transparencies exhibited apparent resolution no better than that of the standard LANDSAT-2 products.

Return beam vidicon (RBV) imagery has shown some potential for distinguishing between chaparral and cleared land in the Lake Casitas area of Ventura County. The panchromatic response of the RBV system limits its analytical value for this type of application, but obvious features of land preparation can be identified.

4.3.2.3 <u>Evaluation of High-altitude (U-2) Imagery for Detection of Avocado Acreage</u>.

NASA U-2 CIR imagery at a scale of 1:130,000 is more useful for situations involving tree-crop agriculture than is satellite data. At 10X magnification of U-2 imagery, individual grove boundaries are apparent. In many cases the trimmed tops and compact appearance of mature trees indicate the presence of citrus. Coarser textures and less linear planting patterns are associated with avocado groves. None of these characteristics is conclusive evidence of avocado or non-avocado groves; especially for younger trees, where textural information is minimal, it is sometimes impossible to determine tree type. An important use of U-2 imagery is the confirmation of those areas suspected of containing tree crops on the basis of satellite image intrpretation. This further isolates those areas that require analysis via large-scale imagery.

Relative age of avocado/citrus trees can be established on the basis of stronger infrared reflectances, larger sizes, and the textural differences possessed by mature trees when compared to younger ones. This is significant in determining the year of planting, and consequently the anticipated year of initial production, for recently planted avocado groves.

Areas newly cleared for planting, such as those in Rancho California, are highly visible on U-2 images. Once again, this characteristic is useful in the confirmation of satellite-derived information. Future clearing can be monitored by comparison of subsequent LANDSAT scenes with archived U-2 imagery. It should be noted that transitions in land use such as have been described have implications not only for estimating future avocado production. Water demand assessments, fire protection services, and tax revenues are among the other categories affected by such changes.

4.3.3 <u>CONTINUING AVOCADO POTENTIAL PRODUCTION RESEARCH</u>

The California Avocado Commission will support the Avocado Production Potential research project in the amount of $45,000 in the grant year 1980-81. The University of California Agricultural Experiment Station, Riverside Campus will support the project with an additional $20,000. The combined funding from the two organizations will therefore match an anticipated $65,000 funding from the NASA University Applications Program for the next grant year.

Under the grant funding for 1980-81 we propose to:

(1) complete the inventory of avocado acreage in California, and establish a working Avocado Production Potential Information system.

(2) continue to develop a method for utilization of LANDSAT imagery to provide intercensal updating of avocado acreage information.

(3) conduct limited basic research in the area of frost pocket mapping to aid in establishing those areas in which frost-sensitive crops should not be planted.

4.3.3.1 Completion of Avocado Acreage Inventory and Establishment of the Avocado Production Potential Information System

It is expected that the 1980-81 grant year will be the final year for the five phases of the research plan outlined in section 4.2.1. This will encompass the inventory of the avocado acreage in the other six counties (Orange, Los Angeles, Ventura, Santa Barbara, San Luis Obispo, and Tulare). The work should proceed much faster than it did in San Diego County as the parcel sizes are much larger. The larger parcels will probably enable the use of smaller scale imagery such as the Landsat and the NASA high-altitude (U-2) imagery.

The design of the Avocado Production Potential Information System will be completed and the system will be tested against the San Diego County data. At the end of the grant year the statewide system will be tested. The San Diego County test will hopefully be performed in conjunction with the annual crop forecast for the 1980-81 avocado season (November 1980 through October 1981).

One of the problems first encountered in collecting attribute data in San Diego County was the transcription of tax assessor data from microfiche records. An arrangement has since been made with the County Assessor to obtain attribute data from their records on magnetic tape.

4.3.3.2 Continuing Investigation of LANDSAT Imagery for Detecting Avocado Acreage

We will continue to analyze LANDSAT imagery in all areas of the state to determine how it can be employed in intercensal updating of avocado acreage in production and in preparation for production. One area of considerable concern is the use of Computer-Compatible Tapes (CCT's) of the EDIPS processed LANDSAT data. The project should have the inhouse capability for processing CCT's by the summer of 1980. This will permit fuller exploration of the EDIPS products than has been permitted by the use of LANDSAT photographic products provided by the EROS Data Center.

The integration of three scales of remotely sensed data--LANDSAT, U-2, and low-altitude imagery--provides a viable approach to the inventory of avocado groves. Some directions that this effort will take in the future are:

1) Techniques for future updating of the data base will focus on the applicability of LANDSAT to this problem. With initial parcel-by-parcel information on the presence or absence of avocado trees based on large-scale imagery, it may be possible to monitor changes through LANDSAT.

2) Maturation of newly cleared and planted avocado groves in Rancho California may result in observable shifts in the spectral responses of the groves from band 5 of LANDSAT imagery toward band 7. If this is found to be the case, the nature and extent of change in signatures associated with the transition from chaparral to bare ground to mature avocado groves can be more acurately characterized.

3) By analysis of the seasonal variations of spectral responses of avocado trees versus citrus trees, it may be posible to arrive at a more definitive method for distinguishing the two crops.

The use of LANDSAT and U-2 imagery has been found to be adequate for the identification of regional trends in current and future tree crop production. Within a single LANDSAT scene, areas containing mature groves and sites of recent clearing can be detected rapidly over a large geographic area. In the future, multi-date LANDSAT analysis promises to be an effective means for monitoring those types of tree-crop land use changes currently being investigated via low-altitude imagery. The resolution of LANDSAT imagery products is inadequate to perform the actual tree-crop inventory. As mentioned above, the potential of EDIES and EDIPS digital format data merits further research.

The actual delimitation of tree-crop areas and cleared zones, the determination of relative tree age, and the assessment of avocado production as potential land use are more successfully accomplished with U-2 imagery than with LANDSAT photographic products. The limited availability and coverage of U-2 makes the preliminary evaluation of LANDSAT data highly desirable, however, at least as a first step. The ready availability of complete LANDSAT coverage is an important consideration for inventory update. When it is available, U-2 imagery may also be effectively employed in the update process.

4.4 DETECTION OF FROST PRONE AREAS USING HIGH-ALTITUDE TIR

4.4.1. Introduction

Frost frequency and severity are key factors in the successful production of avocados and other semitropical and tropical crops. At present, reliable information on frost susceptibility within small geographical areas is scarce. The application of such information is similarly limited. A better understanding of local distributions of frost susceptibility could serve at least two purposes. Firstly, it would permit the delineation of various classes of frost hazard, thereby allowing the grower to avoid high-risk areas or to select particularly frost-resistant varieties for planting in these areas. Secondly, it could provide a partial basis on which to delimit areas of economic avocado production. The maintenance of the avocado production inventory would be easier if only those areas known to be capable of commerical production had to be monitored.

The present network of climatic stations is too sparse to supply frost susceptibility information at the desired level. One purpose of the U-2 thermal infrared (TIR) mission is to fill this gap. Other benefits will also accrue from this experiment.

4.4.2 Mission Objectives

The TIR mapping mission was requested in order to fulfill several current goals:

1) the delineation of frost-prone areas in western San Diego County;
2) the identification of new sites within the same area which are attractive for future avocado production based on low susceptibility to frost conditions;
3) the comparison of results of surface temperature calculations based on four sources of information: NASA-supplied internal linear calibrations, a theoretical "gray-window" atmospheric model for remotely sensed radiation data, and empirical calibration schemes based on concurrent ground measurements, and data from 15 air-temperature

recording shelters operated by the National Weather Service;

4) the development of a general understanding of the applications of such data to agriculture in anticipation of the availability of LANDSAT-D data with very similar characteristics.

4.4.3 Mission Specifications

To achieve the goals outlined in the previous section, an arrangement was made with NASA to fly a U-2 TIR mission over western San Diego County and the western slopes of the San Joaquin Valley. The Daedalus Multispectral Scanner (DMS), with ten channels in the thermal range, was employed as the sensor. The DMS has an optical resolution of 80 feet at the 65,000 foot operating level, an instantaneous field of view of 1.25 milliradians, and a scan rate of 10 lines/second. Channels 11 and 12 of the sensor contain low- and high-gain data for the 10.4-12.5 um TIR band.

The mission was maintained in a ready state until suitable meteorological conditions occurred for the pre-dawn overflight. The necessary combination of near-freezing temperatures, low winds, and relatively clear skies came about on the morning of January 22, 1980. The mission was flown between 6:00 and 6:24 AM local time on that morning.

4.4.4 Meteorological Conditions on January 22, 1980

Between periods of intermittent precipitation during January, 1980, a stationary high pressure ridge persisted off the California coast for several days. The clear weather associated with this ridge permitted nocturnal temperatures to reach freezing in parts of western San Diego County. National Weather Service forecasts also predicted frost conditions for the morning of January 22. On January 21, NASA and UCR personnel began preparations for the mission.

The meteorlogical conditions turned out to be almost ideal. Winds were less than five miles per hour in the San Diego area. Skies were clear and temperatures were not so low that smudging was necessary. The 15 Weather Service stations in the area reported 6 AM temperatures ranging from 32 to 42°F. (No other comparably cold night occurred in western San Diego County subsequent to the mission date.)

4.4.5 Ground Measurements

As the overflight was taking place, UCR personnel were making ground measurements at designated sites within the study area of San Diego County.

Three primary sites were chosen as representative warm and cold surfaces. Lake Hodges, south of Escondido, served as the warm surface. Two large, clean, black-topped parking lots were used as cold surfaces. The sites were selected because they had an area of at least 240 by 240 meters, or 9 pixels, and could thus be identified with at least one full pixel of the scanner data.

At each site, several readings were taken using a Barnes thermal radiometer (10.5-12.5 um sensitivity) aimed vertically in order to obtain the average radiance temperature of the surface. Kinetic temperatures were recorded using thermocouples. Standard-height air temperatures and humidities were also gathered. These data will be used in calibrating sensor data.

4.4.6.1 Initial Analysis

NASA provided a low-resolution facsimile of the imaged area for orientation (Figure 5). A cursory examination reveals the dendritic pattern resulting from cold air drainage down watercourses. Since many new avocado groves are planted on valley slopes, the actual depths of the inversions created by cold air drainage are potentially of considerable significance in assessing the frost hazards at various slope locations. The plateaus appear to be warmer than their flanks in the image, but even within plateaus there is some variation. Mapping of the geometrically corrected, calibrated digital data will permit the identification of particular geographical locations with temperature values. Frost hazard categories can then be developed and mapped.

4.4.6.2 The 'Gray-Window' Model and other Calibration Techniques

The alteration of sensor-received radiance values by the atmosphere will be investigated using a theoretical 'gray-window' model. The principal variables in this model are atmospheric moisture and temperature. Radiosonde data for Montgomery Field, which lies 10 miles south of the imaged area, have been obtained from the Weather Service. The model will use these data to calibrate the image data in order to arrive at surface temperatures. The results of this method will be compared with NASA-supplied calibrations, observed ground radiances, and Weather Service station data in an effort to develop suitable calibration methods for future applications.

4.4.6.3 <u>Applications to LANDSAT-D Data</u>

The characteristics of the DMS data are quite similar (with regard to resolution and band specifications) to the TIR capabilities of LANDSAT-D. The calibration techniques developed for this project may prove useful in the analysis of such satellite data when it becomes available. Furthermore, the present study may suggest some of the advantages and limitations to the use of such data for agroclimatological applications.

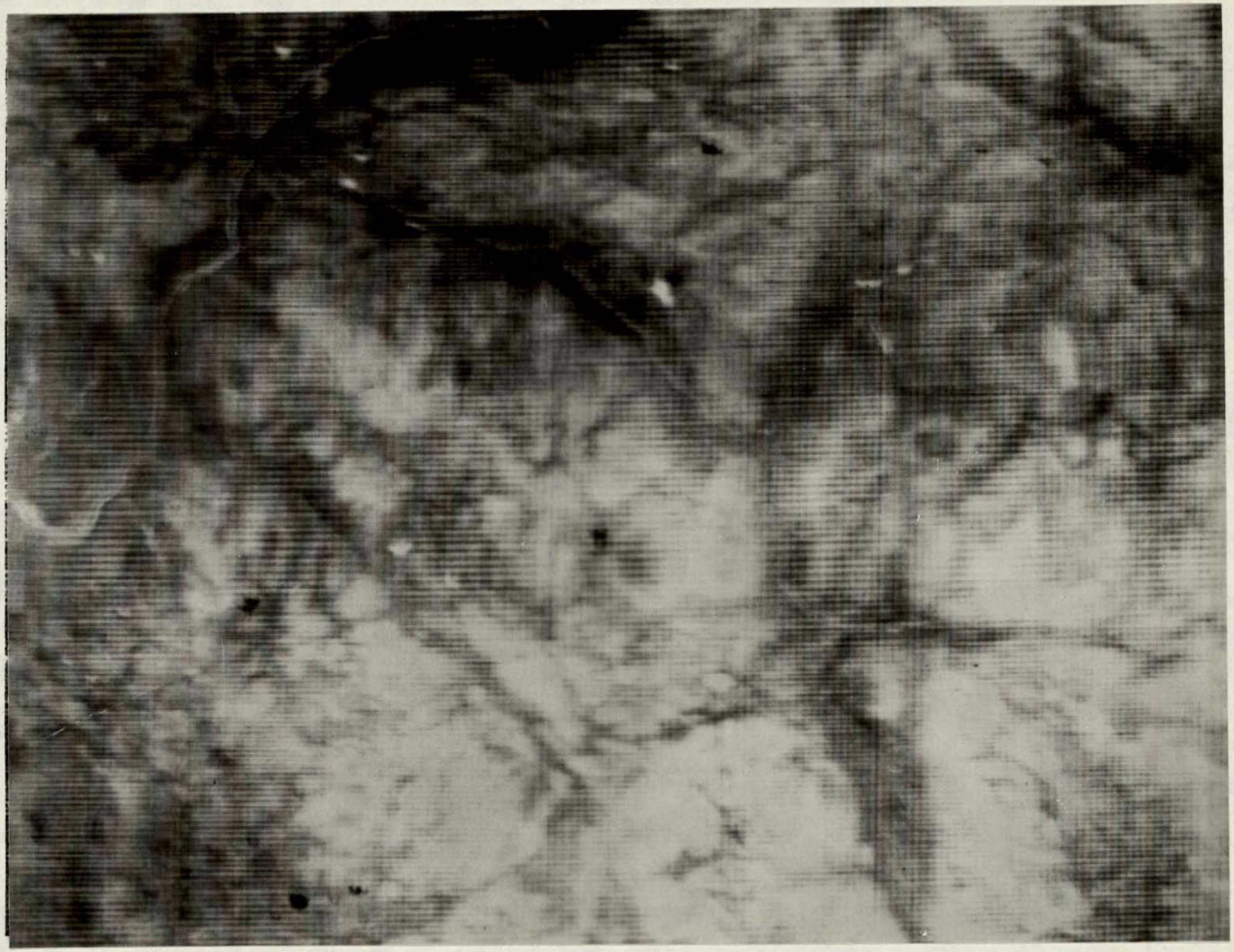

Figure 4-5. Low-resolution facsimile of the Thermal Infrared scan of the San Luis Rey river region south of Fallbrook, California. Scanned at pre-dawn on the morning of January 21, 1980 the image depicts the air drainage (ground temperatures at 32°F (0°C) from the upper plateaus (the warm areas show as white) down the valley slopes (dark areas indicating colder temperatures). The dark areas, if planted to avocados, are "high risk" in terms of frost damage.

CHAPTER 5

REMOTE SENSING CONCEPTS

(A systematic compilation of concepts that have been discovered and/or tested under this NASA grant)

Robert N. Colwell

INTRODUCTION

. These concepts are presented under the following five headings: (1) Problem Definition Concepts; (2) Data Acquisition Concepts; (3) Data Analysis Concepts; (4) Information Presentation Concepts; and (5) Technology Transfer Concepts.

PROBLEM DEFINITION CONCEPTS

1. The "User Requirement" Concept. The "user" is the resource manager and the "requirement" is for information that will better enable him to manage the entire "complex" of natural resources for the area coming under his purvue. Usually the user requirement is best arrived at by answering the following questions in the sequence listed: (a) What should be the policy with respect to an area's resources? Specifically, is the objective to achieve maximum revenue, maximum preservation and enhancement of the environment, or "the greatest good for the greatest number in the long run"? (b) What kinds of resource management plans are needed in order to implement that policy? Specifically, must the resource manager know where to "clear cut" and where to "selectively log" timber, where to permit unrestricted grazing and where to require "rest rotation" grazing and/or where to employ unusually stringent environmental protection measures when mining? (c) What kinds of remote sensing data need to be acquired and what data analysis techniques need to be employed in order to obtain the needed information?

2. The Concept of "Surrogates". If the desired information is not directly obtainable by remote sensing can some closely associated phenomenon be so obtained? e.g., if a soils map is needed, but soils cannot be directly mapped from remote sensing data, can "plant indicators" of soil types be so mapped?

3. The Concept of "Trade-Offs". If there is a strong desire to achieve two mutually incompatible objectives (e.g., (a) highly accurate, detailed, timely information about resources, and (b) very low resource inventory costs) what is the best compromise (e.g., the best "accuracy vs. cost" combination)? For further information see Figure A-1.

4. The "Half-Life of Usefulness" Concept. Assume that a certain kind of resource-related information can be used to maximum advantage only if there is a certain specified minimum time delay between data acquisition and information availability. If there is twice the time delay the information will be roughly half as useful.

5. The "Critical Mass" Concept. Often the use of modern remote sensing technology can only be justified if (a) the geographic area to be analyzed exceeds a certain critical size and/or degree of complexity; (b) the associated kinds and amounts of equipment for data enhancement and analysis exceed certain critical minima; and (c) collectively, the team of remote sensing scientists exhibits at the very least a certain critical amount of the multidisciplinary expertise that is needed for accomplishing the various visual and computer-assisted tasks that need to be involved in analyzing effectively the remote sensing data. Until these "critical mass" components exist, proper exploitation of modern remote sensing technology may not be feasible. Once such critical minima have been established within a particular remote sensing-oriented organization, however, progressively bigger and more sophisticated remote sensing-related tasks can be performed by that organization at progressively more favorable cost/accuracy ratios.

6. The "Flow Chart" Concept. Usually in a remote sensing-related project the following sequence of phases occurs as shown in Table 2 of the main body of this paper: Problem Definition, Data Acquisition, Data Analysis, and Information Presentation. Furthermore there usually must be a sequence of steps taken within each phase. A "flow chart" portrays these various phases and steps in linear fashion, usually with a series of labelled rectangular boxes. The flow chart usually is posted in a prominent place within the remote sensing laboratory. As each step is completed on any given project the person responsible for that step places his initials in the appropriate rectangle and the date and time of completion. The use of a flow chart is well justified when the following combination of circumstances prevails as is often the case: (a) several complex projects are underway at the same time; (b) several shifts of workers are engaged in any given project; and (c) work-stopping "bottle-necks" are likely to develop if any critical step is not completed on schedule or is completed, but without the knowledge of these who are to perform the next step.

7. The "PERT Chart" Concept. Identical with the "flow chart" concept (above) except as follows: At various points in the flow of events several tasks need to be proceeding simultaneously instead of sequentially. To cite one typical example: once a photo mosaic of the area has been made and four prints have been produced from it, the forester, geologist, hydrologist and soil scientist should perform their interpretations simultaneously, each delineating on his own print.

DATA ACQUISITION CONCEPTS

1. The "Synoptic View" Concept. From the standpoint of both the photo interpreter and the photgrammetrist there are great advantages that can result when a large area has been photographed or otherwise remotely sensed from a single point, thereby providing the "single point perspective" that a line scanner does not provide.

2. The "Sensitivity Analysis" Concept. Usually several components are integrated in the making of a given remote sensing-derived product. The accuracy and asociated usefulness of such a product may be little affected by (i.e., relatively insensitive to) the accuracy with which one particular component is known. On the other hand it may be highly sensitive to some other component. Consequently, if the making of the product is preceded by the making of such a "sensitivity analysis", it is possible to allocate time and effort in a highly cost-effective way, component-by-component, in both the data acquisition and data analysis phases.

3. The "Cost vs. Accuracy" Concept. As shown in the following diagram, a new and better remote sensing based technology provides three options when compared to the older technology: (a) greater accuracy at the same cost (compare "1" and "2"); (b) the same accuracy at lower cost (compare "1" and "3"); (c) any of several intermediate improvements in the cost/accuracy ratio (compare "1" with "4").

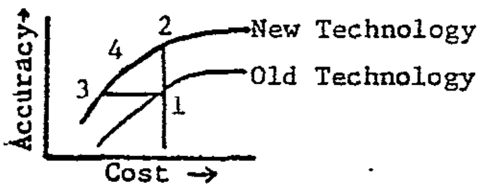

Figure 1. A Typical Cost vs. Accuracy Diagram

4. The "Tone-Sharpness-Parallax" Concept of Image Quality. For a fully illustrated explanation of this concept, see Chapter 2 in the "Manual of Photo Interpretation" of the American Society of Photogrammetry, as cited. Various combinations of these three attributes serve to define (a) the threshold for detection and (b) the threshold for identification of any given resource-related feature.

5. Concepts Regarding the Quality of Digital Data. The quality of digital remotely-sensed data can be adversely affected by a variety of factors including line skips, limited dynamic range, signal attenuation by atmospheric haze, and the excessive width or improper defining of spectral bands. These and more are discussed in the "Manual of Remote Sensing" of the American Society of Photogrammetry (1975).

6. The "Multi" Concept. More information is obtained from multiband photos than from those obtained in only one band. The same is true for multidate, multistage, multi-enhancement, etc. For a fully illustrated explanation of this concept, see Chapter 1 in the "Manual of Remote Sensing" of the American Society of Photogrammetry (1975).

7. The "Signal-to-Noise" Concept. Best illustrated by means of the following example: Assume that an attempt has been made to obtain nine identical photographic images, each recorded separately, but of the same scene, from the same camera station, using the same camera and the same film-filter combination. The nine processed photographs are then placed simultaneously in a "multiple image correlator" which presents to the viewer all nine images combined into a single composite image. Random "noise" due to film graininess, processing, imperfections, etc., is thereby cancelled out, while the "signal" from each feature in the scene is re-enforced. The amount of improvement in the signal-to-noise ratio, as evidenced by the increased sharpness of images, approximates the square root of "n", where "n" is the number of photographs presented to the multiple image correlator". Since in this instance nine photographs were used, there is an improvement of approximately three-fold in the "signal-to-noise" ratio.

8. The "Redundancy of Information" Concept. This concept likewise is best illustrated by a specific example: When multispectral remote sensing is performed simultaneously in many wavelength bands (either optically or electronically) for the purpose of identifying features from their "spectral response patterns" the following generalizations usually apply: (a) three properly selected spectral bands usually are both necessary and sufficient, although there are instances in which only one or two bands will suffice, and (b) if more than these three bands are used there usually is a redundancy of information, which should be eliminated.

9. The "Data Compression" Concept. Assume that, through the use of a multispectral scanner, digital remote sensing has been performed simultaneously in each of nine bands--the digits in each case being indicative of "scene brightness". Also assume that (a) all examples of object "A" can be identified from the spectral response pattern provided by Bands 1, 2, and 5; (b) all examples of object "B" can be identified from the spectral response pattern provided by the Band 4/Band 6 ratio; and (c) no other identifications are required. In the interest of data compression only, the digital data from Bands 1, 2, 4, 5, and 6 need to telemetered to earth in this particular instance; and in further interest of data compression it might be possible for an on-board computer to determine the Band 4/Band 6 ratio, pixel-by-pixel, and telemeter merely the ratio to earth, rather than the 2 bands of digits.

10. The "Ancillary Data" Concept. Frequently the analyst of remote sensing data is confronted with the following situation: (a) certain essential information components cannot be derived adequately from an analysis of the available remote sensing data (e.g., property ownerships, topographic data); and (b) these components are already available from recent surveys of the same area, either in the form of highly usable raw data or adequately refined information. Consistent with the "ancillary data" concept, the analyst may be well advised to use certain items that may be made available to him from these recent surveys.

11. The "Vertical Integration" Concept. Some of the potential users of remote sensing-derived information for any given geographic area may be employed at the local, municipal, or county level, and others at the state, federal or global level. In such instances the concept of "vertical data integration" may be employed in either of the following two ways: (a) data and/or information already acquired at one of the above-stated levels may, with some modification, be integrated into the data analysis scheme needed in meeting the information needs of users at other levels (consistent with the previously-discussed "ancillary data" concept); and (b) by considering at the outset the needs of all levels of users, an integration of those needs may result in the production of a single product that is usable at all levels.

DATA ANALYSIS CONCEPTS

1. The "Human Factors" Concept. The ability of a remote sensing scientist to perform adequately may depend to varying degress on his or her: (a) background of training and experience; (b) visual acuity, especially in relation to the perception of the previously-mentioned tone or color contrast, the sharpness and the stereoscopic parallax attributes of images; (c) motivation; (d) resistance to fatigue during prolonged periods of work; (e) powers of judgement; and (f) ability to employ and interact with various kinds of equipment that have been designed either to assist in the viewing, measuring and plotting of images or in the making of computer-assisted analyses. All of these attributes, and more, are included in the term "human factors".

2. "Machine Factors" Concept. Most of the machines used today by those working with remote sensing data are for "automatic data processing" or (to use a better term) "computer-assisted analysis". At the risk of some oversimplification it can be said that unless such a machine can be provided with remote sensing data in digital form then, to quote the robot, "it does not compute". Of the many image attributes used by the human analyst of remote sensing data (tone, texture, size, shape, shadow, association, etc.) one is far more readily digitized than any of the others, viz., "tone" or "scene brightness". All terms used to describe the various "machine factors" (including "histogram equalization", "unsupervised classification", "clustering", "pixel counting", "band ratioing", and "the nearest neighbor decision rule") rest on this basic premise. The remote sensing scientist who wants to use the machine as his servant must remain cognizant of this fact at all times; otherwise he soon may become the servant of the machine.

3. The Concept of "Binary Choice". Whenever a choice must be made, a borderline must be recognized. If the borderline is distinct the choice is easy. In any given instance the borderline is most likely to be distinct, and the number of troublesome borderline cases is likely to be the fewest, if the choice is merely a "binary" one

(e.g., light vs. dark, rough vs. smooth, large vs. small). Computer scientists have recognized this concept from the outset and exploited it fully through their use of binary decision programs. Human photo interpreters also have successfully exploited this concept through their construction and use of dichotomous (two-branched) photo interpretation keys.

4. The Concept of "Progressive Elimination". This concept is a logical corollary to that of the "Binary Choice" as used, for example, in a dichotomous key. A near-perfect analogy is provided by the progressive elimination "ladder" that is used in a tennis tournament. At each step there is a binary decision (one winner and one loser) until by progressive elmination there is only one winner. Similarly, at each step in a dichotomous key there is a binary decision. One description fits the feature that is to be identified and is accepted; the single alternate description does not fit and is rejected until, by progressive elimination, there is only one type of feature that has survived every step of the elimination process. If the key has been properly constructed and properly used, the surviving type of feature, as a result of "progressive elimination", represents the correct identification.

5. The Concept of Decision Rules. This concept has been adequately described under the three immediately preceding concepts, even though decision rules based on "clustering", "root mean square analyses", band ratioing", and other mathematical treatments may extrapolate far beyond what already has been said.

6. The "Convergence of Evidence" Concept. Often the photo interpreter cannot use a single clue (photo image characteristic) in identifying a feature; instead he must use several clues, none of which is infallible. If most of these clues are detected in any given instance, he deduces the identity of the feature in question by "converging" the evidence provided, collectively, by these several clues.

7. The "Multidisciplinary Conference" Concept. This is a logical extension of the "Convergence of Evidence" concept in that some clues to the identity or significance of a feature are best detected by a photo interpreter from one discipline (e.g., forestry) while other clues are best detected by one from a different discipline (e.g., geology). It follows that a more complete interpretation of features and conditions within the area of interest often can be made through a multidisciplinary analysis and associated conference.

8. The Concept of "Discrimination vs. Identification". Often the remote sensing scientist can discern and draw the boundary between one resource feature (e.g., vegetation type) and another, from his analysis of the presently available remote sensing data, without being able to determine from it the exact type and identity of features on either side of the boundary. In such instances he makes useful boundary delineations, based upon these discriminations, and subsequently relies upon either ancillary data or multistage sampling to make the necessary identifications. The so-called "unsupervised classification" that often is made as the first step in a computer-assisted analysis of remote sensing data entails discrimination but, at the moment, disregards identification.

9. The Concept of "Spatial Filtering". Major resource boundaries (e.g., between predominantly grass-covered and predominantly tree-covered areas) often can be more readily and consistently delineated on imagery of low resolution than on that of high resolution. In such instances the image analyst should be provided with

imagery that has been spatially filtered to remove unwanted high-resolution detail. Two ways in which such filtering can be accomplished are (a) through use of a low-resolution sensor system at the time of data acquisition, and (b) through the "defocussing" of high resolution imagery at the time of data analysis.

10. The Concept of "Elimination vs. Direct Focus". Often the image analyst's objective is singular and highly specific (e.g., to locate all of the bodies of standing water, or all of the anticlines, in a large area). Two search methods are available to him in such instances: (a) the "elimination" method in which a highly systematic, meticulous search is made of each pixel of imagery--although very time consuming, this method usually requires only one search and eliminates the need to subject all or part of the area to subsequent re-examination; and (b) the "direct focus" method, in which attention is immediately concentrated upon those portions of the imagery which (e.g., because of the overall lay of the land) are known to be the ones most likely to contain examples of the features of interest. This latter method often produces adequate information both quickly and economically; but if it does not, the meticulous "elimination" method may then need to be resorted to, with a consequent duplication of search efforts in some of the areas.

11. The "PPX" Concept. Through use of this concept it is possible to determine the intensity with which each stratum of a grossly stratified area might most efficiently be subsampled to acquire more detailed information. In this three-letter designation the "PP" portion means, in the jargon of the statistician, "probability in proportion to...". The "X" portion may pertain to the expected timber volume, animal carrying-capacity, or other attribute, stratum-by-stratum based on the initial classification. If, in any given instance, the initial gross stratification has been accurately done with the "X" attribute in mind, use of the "PPX" concept serves to distribute a finite number of subsamples in the most cost-effective manner.

12. The "Confusion Matrix" Concept. The accompanying matrix serves to tabulate, in a readily comprehended manner, each of the following important results (as obtained in a representative test) relative to the ability to identify features A, B, C, D, and E from a given type of remote sensing data: (a) the percent correct idetnifications, by type; (b) the percent "omission errors", by type; and (c) the percent "commission errors" by type. The latter two percentage values quantitatively highlight the types of confusion, thereby focussing future efforts that are designed to improve classification accuracy.

"GROUND TRUTH"

REMOTE SENSING RESULTS	A	B	C	D	E
A	90	15	0	0	0
B	10	85	0	0	0
C	0	0	100	0	0
D	0	0	0	80	10
E	0	0	0	20	90
Total	100	100	100	100	100

Figure -2. A Typical Confusion Matrix

13. The "Complexity of Structure" Concept. With respect to the resource attribute that is to be identified by means of remote sensing, some geographic areas are very simply structured while others are very complexly structured. If, for example, the attribute is "forest type", a complexly structured area is likely to have heavily dissected steep topography with widely varying geologic parent materials and soils, supporting many species, age, and vigor classes of trees that are highly intermingled. If a preliminary remote sensing feasibility study with respect to forest type classification has been made within a test site that is much more simply structured in each of the above respects, there is likely to be gross dissatisfaction when one seeks to apply the same remote sensing technology to the more complexly structured area. For this reason, the "complexity of structure" of an area must always be considered at the outset as one considers the potential usefulness and limitations likely to be associated with the use of remote sensing in that area.

14. The Concept of "Signature Extension." The combination of scene brightness (photographic tone) values exhibited by a given type of resource feature when it is remotely sensed in each of several bands of the electromagnetic spectrum is known as its "spectral response pattern" or "signature". In the past it has sometimes been erroneously presumed that once a resource feature's signature has been established in a given test site of limited size, the same signature could be applied to that feature for a vast "extended area" that was either adjacent to or, in some instances, even far removed from the test site, itself. In consequence, "signature extension" tests should be part of the feasibility analysis that is made in instances where such difficulties might arise.

15. The Concept of "Change Detection". It is axiomatic that "renewable" natural resources (timber, forage, water, etc.) are constantly undergoing change. The same is likely to be true, even for "non-renewable" resources (minerals, fossil fuels, etc.) when man is actively exploiting them. Not only is it desirable to have an initial inventory in all such cases but also a periodic re-inventory so that both beneficial and potentially beneficial changes can be detected through a process known as "monitoring". The techniques by means of which a remote sensing scientist can detect changes in the resource attributes of an area (e.g., through the making of a comparative analysis of sequentially-acquired remote sensing data) are known as "change detection" techniques.

16. The Concept of "Ratioing". As previously indicated, the multiband spectral response pattern for a given type of resource feature commonly is expressed quantitatively by tabulating its "scene brightness" or "photographic grey scale" values, band-by-band. Differences in these values form the primary basis for differentiating among resource features when multiband remote sensing has been employed. This is true whether the resource identifications are being made by direct visual analysis or by computer-assisted analysis. Thus, it is the ratio between these individual scene brightness values that governs, in large measure, the color with which a resource feature is registered on a multiband color composite that is used in direct visual analysis; and it likewise is the ratio which (partly in the interest of "data compression") is used to facilitate the making of computer-assisted analyses of these same features.

17. The Concept of "Pixel Counting". The instantaneous field of view of any line scanner type of remote sensing device (such as the multispectral scanner used on the Landsat vehicles) governs the size of the individual picture element or "pixel".

For any given flight altitude the corresponding ground area covered per pixel by such a scanner therefore is readily determinable. Through proper computer programming, each pixel theoretically can be automatically classified in terms of the resource type on the ground for which it has recorded the multiband scene brightness values. In addition, through "pixel counting" the computer can record a running total of the number of pixels encountered, by type of resource feature represented. Thus, for any given resource type, the product of pixel count for that type times land area per pixel permits a determination readily to be made of the total area occupied by that type within the scene that has been classified.

18. The Concept of "Improvement-Through-Experience". Numerous tests have shown that experience gained in some initial use of modern remote sensing technology permits improvements to be made in subsequent applications of a similar nature. For example, with respect to two-stage sampling (aerospace and ground) for purposes of timber volume estimation, this concept of improvement through experience is suggested by the accompanying diagram, (Line 3 vs. Line 4).

SURVEY METHOD	ACCURACY OF ESTIMATE		
	Volume Per Unit Area In Each Stratum	Total Area In Each Stratum	Total Volume In Each Stratum
1. Ground Suvery Alone	HIGH	LOW	MEDIUM
2. Photo Survey Alone	LOW	HIGH	MEDIUM
3. Ground Survey Plus Photo Survey-1st Yr	HIGH	HIGH	HIGH
4. Ground Survey Plus Photo Survey-10th Yr	HIGHER	HIGHER	HIGHER

Figure 3. An Example of the Concept of "Improvement-Through-Experiences"

INFORMATION PRESENTATION CONCEPTS

1. The "Multiple Overlay" Concept. To an ever-increasing extent, the resource manager is charged with managing, as intelligently as possible, all components of the entire "resource complex" throughout the area that falls under his purvue. Furthermore, in doing this he must give proper consideration both to (a) the short-term and long-term revenue potentially derivable from each resource component and (b) the short-term and long-term measures that might best preserve and/or enhance the environment. If he is to approximate the achieving of this multifaceted goal he must have information about each resource type and its condition, area-by-area, and similarly specific information with respect to various environmental considerations. It is obvious that the totality of this

information, even when available, cannot be placed on a single map; instead various "thematic maps" need to be prepared. Each of these maps, in turn, could be made more legible if the need for including much of the "base map" information on it could be eliminated. The foregoing has led to increasingly greater use of the "multiple overlay" concept by resource managers in recent years. As indicated by the accompanying specific example, each overlay deals with only one important attribute (e.g., terrain cover or the intervisibility of features). These overlays can be superimposed, individually or in various combinations as appropriate, with respect to a base map that emphasizes primarily the planimetric and/or topographic features of the area.

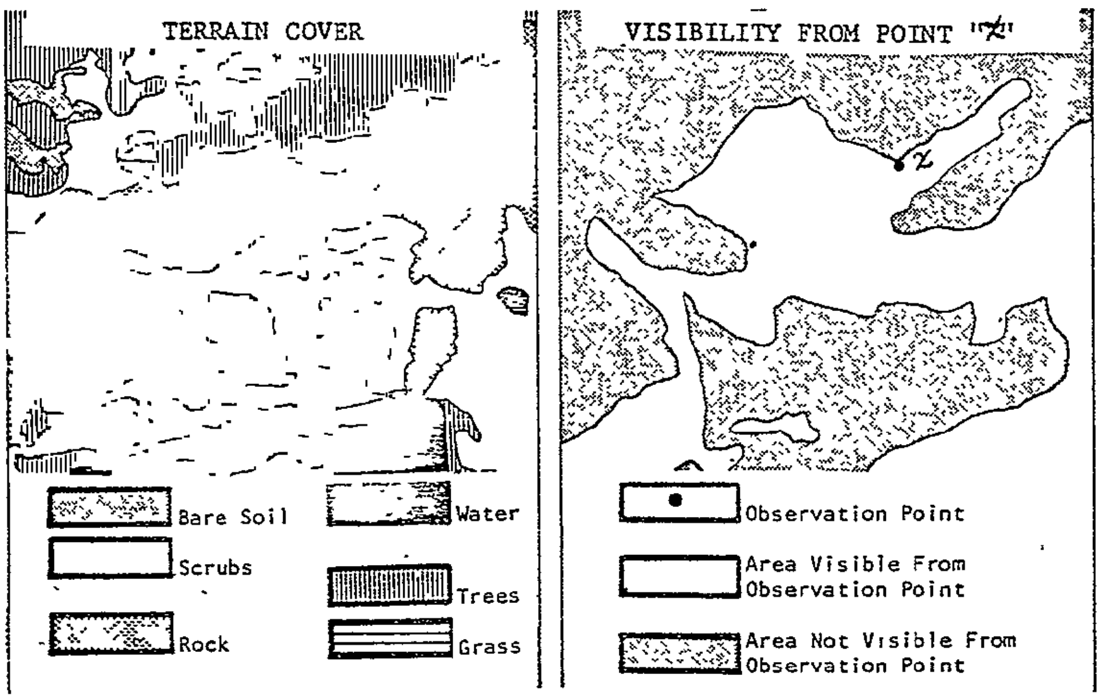

Figure 4. Two Thematic Maps for the Same Area

2. The "Color Coding" Concept. The comprehensibility of a map or overlay usually can be improved if each feature of importance is assigned an appropriate color (e.g., various shades of green for various vegetation types; various shades of yellow for various categories of resource management problems; and bright red for areas having a high potential for the conduct of mining operations).

3. The Concept of "Synthetic Stereo". Most of the resource-related analyses that must be made of remote sensing imagery are greatly facilitated if the terrain that is being analyzed can be perceived in all three dimensions, i.e., stereoscopically. Space photography usually is very deficient from the standpoint of stereoscopy because of its limited spatial resolution, its adverse base/height ratio, and (in the case of line scanner imagery such as that provided by the Landsat multispectral scanner) the absence of single point perspective views. In areas for which a topographic map already exists, this stereoscopic deficiency can be overcome "synthetically", exploiting the fact that the higher the elevation of a terrain feature the greater must be the convergence of the image analyst's two lines of sight, as he views a stereo pair of images, if he is to perceive the terrain three-dimensionally. If, for example, a stereo pair of a Landsat MSS scene is to be produced, as in Figure A-5, the right member of the stereo pair can consist

erely of the uncorrected Landsat imagery, deficient though it is in relief isplacements. The left member of the stereo pair, however, while seemingly lentical to right member, is given "synthetic" relief displacement even while : is being printed from the same digital data as were used in printing the ight member. This is done by thrusting each elevated feature to the right when ne left member is being produced. The greater the terrain elevation (as iscerned from the matching topographic map) the greater the thrust to the right nat is given to its image on the left member of the stereo pair.

Figure 5. A "Synthetic" stereo pair of Landsat MSS images, produced by the means described above. (Courtesy of U.S. Geological Survey).

The "Photo Surface Model" Concept. Often the resource-related features of a area are closely correlated to the topography, thus making it desirable to rtray the area by means of a three-dimensional model, the surface of which is photographically reproduced print (in black-and-white or in color). Such a oto surface model can be produced as follows: (a) By means of a Kelsh plotter, other overhead stereoscopic projector, a topographic map is prepared from a ereo pair of vertical photographs. (b) With the aid of this map a three-dimensiona del is prepared at essentially the same scale as the map and with the same vertical aggeration as was provided by the original stereo pair of photographs. (c) The sulting smooth-surfaced model is sealed in its entirety to make it waterproof, d then coated in the darkroom with the same photo-sensitive emulsion as would used in making paper prints. (d) Through the use of previously-established gistration marks, the photo sensitized model (while still being kept in the dark) properly positioned on the tracing table of the overhead plotter in which the iginal stereo pair of photos still remains positioned. (e) Light is projected rough one or both projector "buckets" onto the model, thus photographically posing its surface. (f) The entire, waterproofed model is then subjected to the same photographic processing solutions as would be used in making a conventio photographic print. The result is a product that combines the advantages of photographic detail with the three-dimensional configuration of the terrain.

5. The Concept of "Compatibility of Formats". Some kinds of remote sensing-derived information are best presented to the resource manager by means of a series of thematic maps; other kinds by means of topographic maps, three-dimensional models, or annotated photo mosaics. It follows that he can best comprehend the total situation with respect to the resource complex of the a if he not only has all such products but has them in compatible formats with respect to scale, legends, color codes, and the total geographic area encomp by each.

6. The Concept of "Multiple Use of Information". When remote sensing-deriv information is being prepared for presentation to the resource manager, consideration should be given to the many potential uses and users of this information. Thus, while the previously mentioned products, collectively, may best suit the direct needs of the resource manager, himself, they may ne to be converted into lantern slides (sometimes even in "vectograph" or "anag form) for presentation to large audiences, as in open hearings. In addition greatly simplified illustrations may need to be prepared for inclusion in a brochure or in an environmental impact statement or, as previously indicated resource managers employed at various levels of governments.

TECHNOLOGY TRANSFER CONCEPTS

1. The Concept of "Appreciation vs. Adoption". In any given organization, modern remote sensing technology has not been adopted by its resource manage until the following conditions exists: The top level decision makers are sufficiently convinced of the usefulness of that technology for solving cert resource related problems that (a) they routinely consider using it, as each such problem arises, and (b) they then forthrightly direct that it be used i each appropriate instance. Thus adoption, by this definition, goes far beyo mere appreciation that remote sensing is a remarkable new technology having potentially great usefulness to resource managers in general.

2. The Concept of "Requirements for Adoption". If a particular aspect of m remote sensing technology is to be adopted in any given instance, the decisi maker needs to be convinced of its simplicity, direct applicability, continu availability and economy, and, in many instances, also of the expeditiousness speed with which the desired information can be obtained through its use.

3. The Concept of "Progression Toward Adoption". If the top level decision is to become convinced that he should actually adopt modern remote sensing technology in all appropriate instances he ordinarily must be made to progre toward that viewpoint through the following succession of steps: awareness, interest, evaluation, trial, and adoption.

4. The Concept of "Deterrents to Adoption". The primary deterrents to the adoption of modern remote sensing technology by an organization's top level decision makers are oversell, overkill, under-training, under-involvement, spurious evaluation, misapplication, and the "not-invented-here" syndrome.

: "Maintenance of Momentum" Concept Too often a resource manager or ss is given only superficial exposure to the marvels of modern remote ; technology through an "appreciation" type of course from which he :es with great enthusiasm. Almost always there is no follow-up to ensure ls organization will begin to put this technology to practical use. ıently, only a short time later he very likely will have lost all of the ım that had been instilled in him during the course. For this very reason lifficult if not impossible to re-instill that momentum in such an lual at some future date. In numerous instances the present writer has :hat the following is the key to solving this "maintenance of momentum" n: By prior arrangement each attendee of the remote sensing appreciation brings with him to that course a specific unsolved resource inventory/ nent problem with which his organization is confronted. Also by prior ication with the instructional staff for the course, he brings with him : staff procures for him) the Landsat MSS data tapes and/or aerial :aphy of his problem area. During the concluding phases of the course, supervision of the instructional staff, he applies to this specific ı and to these specific types of remote sensing data the data enhancement :a anlysis techniques that have been dealt with earlier in the course. ; way he leaves the course having "solved" this specific resource ›ry/management problem. Almost invariably he can scarcely wait to field ıis analyses, refine and correct them as necessary, and then implement ıagement measures that are dictated by such analyses. From this success then progress to additional remote sensing-related problems. Thus ıentum is maintained.

: "Procedure Manual" Concept. As the momentum-filled trainee seeks to :s from his initial success to the solution of some similar or more :d inventory/management problem, he is likely to find that he has forgotten ı important details about the various step-wise procedures which he :d, under staff supervision, as he completed the previously mentioned Consequently he is likely to find very useful a remote sensing-based ıral manual, or series of procedural manuals, of the type recently :ed and tested by the present writer and his associates.

. "Technical Assistance" Concept. Even with the benefit of formal training :rn remote sensing technology and even when equipped with various procedural that have been issued for his retention, the resource manager is likely rience the need for technical assistance from those having greater expertise thus far has been able to acquire. Without such occasional assistance he ly to make serious mistakes on occasion. In that event modern remote sensing ogy is likely to be discredited by him (and perhaps needlessly so), thereby g or completely thwarting "technology acceptance". However, if he is he combination of (a) Procedural Manuals and (b) Technical Assistance, as iate, the likelihood that such an inappropriate result will occur is greatly hed.

APPENDIX "A"

ITEMIZED SUMMARY OF INFORMATION
PERTAINING TO THIS NASA GRANT

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PERTAINING TO THIS NASA GRANT

Note: The following itemized summary consitututes an updating of information as originally requested in a letter from the Manager of NASA's University Application's Program to the Principal Investigator of our NASA Grant, NGL 7220. Items and headings are as contained in that letter.

ITEMS 1 and 2: LISTING OF PROJECTS AND COOPERATING AGENCIES FOR THE YEAR 1979

IRRIGATED LANDS ASSESSMENT FOR WATER MANAGEMENT

OBJECTIVE: To identify and map all of the irrigated lands that exist throughout the state of California (100 million acres). In addition, research on the utilization of digital analysis for estimating irrigated acreage and the determination of specific crop types (manual and digital analysis) is also underway in selected test sites. The system utilizes multi-temporal Landsat data, medium scale aerial photography and/or ground data as inputs to a multiphase sampling procedure designed to produce the statewide estimate. In addition to defining the classification techniques needed to discriminate irrigated land (i.e., band ratioing, supervised, unsupervised classification), work on the registration of several dates of Landsat as well as north-south orientation is currently underway. Work on crop type determination is presently confined to determining confusion classes and making preliminary recommendations for classification techniques.

Cooperating Agencies: NASA, California Department of Water Resources

Data Sources: Landsat, Ground Data

FUEL MAPPING IN RELATION TO THE MANAGEMENT OF BRUSHLANDS AND IN MENDOCINO COUNTY, CALIFORNIA

(This is a portion of the work done under the present multi-campus project - NASA NSG 7220)

OBJECTIVE: To achieve the effective operational use of modern remote sensing techniques as an aid to the mapping of fuels and the management of brushlands and timberlands in Mendocino County, California. Has dictated numerous control burning operations.

Cooperating Agencies: NASA, California Department of Forestry, California Department of Fish and Game, Mendocino County Board of Supervisors, Mendocino County Planning Commission, Mendocino County Fuel Management Committee, U.S. Forest Service, U.S. Bureau of Land Management, U.S. Bureau of Indian Affairs

Data Sources: Landsat, Aircraft, Ground Data

MULTISTAGE SAMPLE DESIGN FOR WILDLAND ENVIRONMENT

Subcontract No. 183408-A from

Electromagnetic Systems Laboratory (ESL), Inc.

OBJECTIVE: To develop a multistage sampling design for a test site in Arizona; to help bring about technology transfer to the user agency, (BLM-USDI); and to provide quality control of project implementation activities. The implementation plan has been presented to BLM personnel. Sampling systems for three major ecosystems (Rangeland, Woodland and Forestland) were developed. For each major ecosystem the following information was determined and documented for given levels of inventory accuracy:

1) Sample unit dimensions and layout
2) Sample allocation procedures
3) Sample unit selection procedures
4) Satellite and aircraft data acquisition procedures
5) Measurement procedures at each sample stage
6) Quality control procedures
7) Data Analysis and summary procedures

Cooperating Agencies: NASA, BLM, ESL, Inc.

Data Sources: Landsat, Aircraft, Ground Data

DEVELOPMENT OF ANALYST INTERPRETER (AI) PROCEDURES (NAS9-14565)

OBJECTIVE:

1) To examine the variation in crop spectral response patterns due to the occurrence of episodal events such as drought and to sufficiently characterize the variation so that analyst labeling error can be minimized.

2) To adapt and expand LACIE-like technology in the area of analyst labeling and multitemporal interpretation of Landsat data to the problem of crop identification in a multicrop situation, specifically corn, soybeans and other summer crops.

Cooperating Agencies: USDA, NOAA, NASA

Data Sources: Landsat, Aircraft, Ground.

REMOTE SENSING-AIDED GROWTH MODELING FOR CONIFER REGENERATION IN THE NORTHEASTERN SIERRA NEVADA RANGE (NASA Grant NGL 05-003-404)

OBJECTIVE: Development of a methodology for generating and successively incorporating multivariate information into a decision logic for evaluating forest growth potential over large environmental areas. Development, testing, and application of the predictive growth potential model required a number of data types. These included Landsat-2 MSS data, NOAA-5 VHRR data, Defense Mapping Agency/USGS Topographic data, and soil data. Model elements included Albedo, Terrain, Temperature, Net Solar Radiation, Potential Evapotranspiration (ETP) and Soil Plant Available Water (PAW). Based on numerous statistical analyses, a refined set of variables was selected for the model. The model was used to estimate Potential Growth Rate (PGR) over a large, ecologically diverse watershed. The variables used were ET, PAW, and Sine and Cosine of Aspect.

Cooperating Agencies: NASA, USFS, BLM, Plumas and Kern Counties

Data Sources: Landsat, NOAA, Aircraft

PROCEDURAL MANUAL FOR DEVELOPING A GEO-BASE INFORMATION SYSTEM (NASA NGL 05-003-404; multicampus)

Recognizing the ready availability of information about topography, cultural features and other terrain characteristics (e.g. through the use of DMATC Digital Terrain Tapes) our remote sensing scientists have demonstrated how such information can be merged with LANDSAT-derived land cover information into an integrated geo-base information system. They also have prepared a Procedural Manual on how to construct and use that system. As a result many other groups are now using the system, either in its original form or in a suitably modified form.

Cooperating Agencies: NASA, USGS, JPL

Data Sources: Landsat, DMATC Digital Terrain Tapes, Ground Data

WATER DEMAND STUDIES IN SOUTHERN CALIFORNIA

(NASA NGL 05-003-404; multicampus)

As an outgrowth of our water demand studies we have developed 2 Procedural Manuals dealing, respectively, with "Mapping Land Use from Remotely Sensed Imagery" and "Construction and Use of a Spatial Information System." The latter system consists of a suite of related computer programs which can be used to perform selected tasks with respect to the processing of information about the natural resources of an area. That system already has been successfully used in relation to 4 major tasks of concern to the resource manager: (1) Map Data Encoding; (2) Geographic Data Base Creation; (3) The Production of Graphic Output in the Form of Computer-Generated Maps; and (4) Data Structure Conversion.

Cooperating Agencies: NASA, California Department of Water Resources; Los Angeles Water and Power Commission.

Data Sources: Landsat, U-2 Photography, Ground Data.

APPLICATION OF REMOTE SENSING TO WATERSHED RUNOFF PROBLEMS

(This is a portion of the work done under the present multicampus project - NASA NSG 7220)

OBJECTIVE: Develop remote sensing-aided storm runoff predictions. Has led to planning and constructing appropriate flood control facilities such as dams, debris basins and spreading ponds.

Cooperating Agencies: NASA, Kern County Water Agency, California Department of Water Resources; California Department of Food and Agriculture.

Data Sources: Landsat, Aircraft (including thermal and microwave); Ground Data.

WATER QUALITY MAPPING AND LOCATION OF ENTRAPMENT ZONE
IN SAN FRANCISCO BAY DELTA USING REMOTE SENSING TECHNIQUES (NASA Grant NSG

OBJECTIVE: Development of a procedure which combines remotely sensed data with surface data for mapping selected water quality parameters in the San Francisco Bay Delta and locating the entrapment zone within the study area. Based on statistical analyses, four models were developed, tested, and applied to estimate the following water quality parameters: Electrical Conductivity, Chlorophyll, Turbidity, and Suspended Solids. The models used spectral radiance values from the OCS as input to predict these parameters. The correlation coefficients obtained ($R_{EC} = 0.948$, $R_{Chl} = 0.934$, $R_T = 0.791$, and $R_{SS} = 0.609$) indicate that a relationship between these parameters, spectral radiance and location of an "entrapment zone" exists and can be used with repetitive satellite coverage to monitor the migration and quality of this zone.

Cooperating Agencies: NASA: California Department of Water Resources; Water Research Institute of the University of California.

Data Sources: Landsat; U-2 (Ocean Color Scanner Data and Color IR Photography); Boat Truth on the 4 parameters.

RIPARIAN VEGETATION MAPPING PROJECT

OBJECTIVES:

1. To map and determine extent of riparian vegetation in Lassen and Modoc Counties.
2. To develop an extensive inventory methodology to later be used in a state-wide assessment of riparian vegetation condition. The riparian vegetation data collected in this project provides the information required by the Department of Fish and Game to properly manage and conserve this dwindling natural resource. The methods developed can be used in future studies necessary to meet changing information and management needs.

Cooperating Agencies: California State Resources Agency, Department of Fish and Game, U.S. Fish and Wildlife Service.

Data Sources: Landsat; USGS Orthophoto mosaics; Color IR Photos from Light Aircraft; Ground Truth.

MULTISPECTRAL DETERMINATION OF SOIL MOISTURE

OBJECTIVE: Development of linear combinations of multivariate algorithms to predict soil moisture through the remote sensing of different crop and bare soil conditions.

Cooperating Agency: Texas A and M University

Data Sources: Aerospace photography; synthetic aperture radar data from Seasat; ground truth.

INCORPORATING COLLATERAL DATA IN LANDSAT CLASSIFICATION AND MODELING PROCEDURES

OBJECTIVE: To identify existing models and procedures for spatial modeling and to apply them to selected data sets and thus to demonstrate their Landsat-related used.

Cooperating Agencies: Ventura County; U.S. Geological Survey.

Data Sources: Landsat; terrain data sets; collateral ground truth.

ANALYSIS OF SEASAT SAR DATA FOR THE DETECTION OF OIL ON THE OCEAN SURFACE

OBJECTIVE: To evaluate the feasibility of a spaceborne imaging radar system, viz. the SEASAT-A SAR System, for the detection and measurement of marine oil accummulations.

Cooperating Agencies: NOAA; U.S. Geological Survey.

Data Sources: Synthetic aperture radar from SEASAT; collateral ground truth data.

SOILS MAPPING OF THE SAN BERNARDINO AND ANGELES NATIONAL FORESTS

OBJECTIVE: To update and improve existing soils maps of these forests.

Cooperating Agency: U.S. Forest Service

Data Sources: Aerospace photography; existing soils maps.

THE ROLE OF LAND USE AND VEGETATION IN ESTABLISHING SPATIAL RISK OF FOREST FIRES IN THE CAJON PASS AREA OF CALIFORNIA

OBJECTIVE: To determine the extent to which various land uses modify wildland fire hazards in Southern California.

Cooperating Agencies: U.S. Forest Service; Pacific Southwest Forest and Range Experiment Station (Agreement No. 54)

Data Sources: Aerospace Photography; existing vegetation and land use maps.

ITEM 3: FUNDING OF THESE PROJECTS *

Contract/Grant	Period	Total U.C. Allocation
NASA NAS9-14565	11/78 - 11/79	300,000
NASA NGL5-003-404 (multicampus)	5/78 - 4/79	195,000
NASA NSG 5256 (multicampus)	5/78 - 8/79	20,000
NASA NSG 2207 (multicampus)	1/79 - 12/79	270,000
NASA NSG 7220 (multicampus)	5/79 - 4/80	225,000
ESL #183408 (subcontract to NAS9-15339	1/79 - 12/79	12,000
CDF-S-1729	4/79 - 12/79	32,000
TOTAL:		1,054,000

* Only projects funded at greater than $10,000 are listed.

ITEM 4: COMMERCIAL SPIN-OFF

To date our efforts to document commercial spin-off resulting from our research efforts have been concentrated under NASA Grant 7220, "Applications of Remote Sensing to Selected Problems in California." With respect to that project:

a. The U.S. Forest Service officially estimated one year ago that "damage in excess of $15 million" would likely have occurred by now in the Thatcher Creek (Mendocino County) Drainage alone had not various remote sensing-aided fuel management measures been implemented, including the construction of fire breaks at strategic locations in highly flammable brushfields.

b. That estimate is now being increased commensurately with our production of remote sensing-derived information about the Etsel Creek Drainage in Mendocino County and comparable areas in Colusa and Shasta Counties, as we progress toward complete and self-sustaining adoption of these remote sensing techniques by the U.S. Forest Service.

c. Similar savings are anticipated soon as a result of (1) the construction of flood control facilities in the San Joaquin Valley, based on our remote sensing-derived information and (2) the avoidance of frost-susceptible areas, as new plantations of avocado trees are established in Southern California.

ITEM 5: EDUCATIONAL ACTIVITIES

a. Conferences, workshops, briefings, etc.

1. In February, 1979, for the seventh year in succession, our remote sensing scientists, under funding by the University of Alberta, traveled to Edmonton, Canada to provide 1-1/2 days of instruction at a week-long annual remote sensing conference of 60 attendees. We are scheduled to present the eighth such session in February, 1980. Virtually all of this instruction continues to be based on our findings under two of the previously-listed NASA grants: NSG 7220 and NGL-05-003-404.

2. In November, 1979, personnel of our Remote Sensing Research Program presented a University of California Extension course entitled, "Applied Remote Sensing for Soil Inventory and Assessment." That course was presented at Berkeley and at nearby NASA remote sensing test sites.

3. In March, 1979, our RSRP personnel presented a course on "techniques for Use in Multistage Sampling," with cooperation provided by both NASA and EROS.

4. Representatives of our multi-campus group presented the following at the Western Regional Remote Sensing Conference in Monterey, CA. in October, 1979. A keynote paper; a luncheon address; and a summary of the 3-day conference.

5. CIRSS Task Force participation, NASA-ARC.

6. Helped teach the California Forest Soils Course. Sponsored by Soc. Am. Foresters, Shaver Lake, CA., October, 1979.

b. Number of remote sensing courses offered annually on various campuses of the University of California: 7 undergraduate courses attended by a total of about 300 students; 4 graduate courses attended by a total of about 80 students.

c. Number of faculty and research assistants involved in b.: about 6 and 8, respectively.

d. Regarding theses completed or in progress, see final item of this summary.

ITEM 6: LISTING OF MEANINGFUL AGENCY CONTACTS

a. Three joint meetings per year in Mendocino County with local representatives of the U.S. Forest Service, the California Department of Forestry, the Bureau of Land Management, the Bureau of Indian Affairs and the Mendocino County Board of Supervisors, Planning Commission and Fuel Management Committee.

b. The same during the past year in both Shasta and Colusa Counties.

c. Two joint meetings per year in Plumas County with local representatives of the U.S. Forest Service, the Soil Conservation Service, the California Department of Forestry and the Plumas County Board of Supervisors.

d. Three meetings per year in Kern County with representatives of the Kern County Water Agency.

e. Two meetings per year in Ventura County with representatives of the Ventura County Planning Commission.

f. Approximately four meetings in Southern California per year with representatives of each of the following groups: (1) the Avocado Advisory Board, (2) the Los Angeles Planning Commission, (3) the Los Angeles Water and Power Company, (4) the Citrus Grower's Association, and (5) the Bureau of Land Management.

g. Approximately two meetings per year with representatives of Governor Brown's Office of Planning and Research.

h. Approximately eight meetings per year with NASA-Ames personnel of the Western Regional Applications Program.

i. Approximately eight meetings in Sacramento or on various university campuses each year with representatives of the California Resources Agency, the California Department of Agriculture, the Environmental Data Center, and the Statewide Remote Sensing Advisory Group.

j. Other agency contacts are as summarized in Item 7, below.

ITEM 7: VISITING DELEGATIONS AND SCIENTISTS

Dr. S.J. Titus
Department of Forest Science
University of Alberta
Edmonton, Alberta, Canada

Mr. Sipi Jaakola
Program Manager
Technical Resource Centre of Finland
Laboratory of Land Use
Otakaari
02150 ESPOO 15 Finland

Dr. Moshen Fakhrai
Iran Military Institute
Tehran, Iran
(in residence for six months at RSRP on Berkeley campus)

Mr. Jean Paul Malingreau
Jakarta, Indonesia

Dr. Hsiao-Fang Li
Commission of International Natural Resources
Academia-Sinica, Peking
People's Republic of China

Prof. Nick Muhlenberg
Department of Forestry
Penn State University
College Park, Pennsylvania
(in residence for six months at RSRP on Berkeley campus)

Space and Life ~~Biological~~ Sciences Directorate
and Earth Observation Directorate Delegation
NASA-Johnson Space Center
Houston, Texas
(12 people for two days at UCSB and UCB, respectively)

People's Republic of China Remote Sensing Delegation
Sponsored by Committee on Scholarly Communication
with the People's Republic of China
National Academy of Sciences, Washington

Dr. eng. Paolo F. Tonani
Instituto di Topografia, Fotogrammetria e Geofisica
Milan, Italy

Dr. Sam Hui
Assistant Chief Hydrologic Engineer
Bechtel, Inc.
San Francisco, California

Dr. Graeme Tupper
Division of Land Resource Management
CSIRO, Deniliquin, N.S.W.
Australia

Dr. I. Rasool
Chief Scientist, OSTA
NASA-Headquarters

Colonel Alberto Viola
and Carlos Viola
Aero-Terra, S.A.
Argentina

Dr. Alberto Geraci
University of Catania
Italy

Approximately 40 visits by individual scientists or by small groups have been made to the remote sensing facilities on various campuses of the University of California during the past year.

Other visitors to our U.C. Riverside facility include (1) representatives from the Defense Mapping Agency interested in UCR's remote sensing-based Geo-Information System and (2) an average of two visitors per month from JPL in Pasadena by personnel cooperating with UCR and BLM on various remote sensing studies.

ITEM 8: OTHER SUGGESTIONS

a. It might be of some benefit to include periodic listings that might be entitled "Special Recognition", much as is done in each annual report to NASA from the Space Sciences Laboratory of the University of California. The page which follows is one that has been extracted from the "Remote Sensing Section" of the most recent of those annual reports.

b. A listing of Ph.D. and Master's degree theses emanating from our work might also be included to good advantage. A current example of such a listing from our multicampus group constitutes the concluding item of this summary.

SPECIAL RECOGNITION

Professor R.N. Colwell

Continues to serve as Editor-in-Chief of the Manual of Remote Sensing - Second Edition. This 2500-page manual is being prepared by more than 250 contributors under auspices of the American Society of Photogrammetry.

Has just been selected to give the feature address at the annual meeting of the Society of Sigma Xi to "University Triangle" members at Raleigh, North Carolina.

Professor John E. Estes

Continues to serve as overall coordinator and editor-in-chief for all of Volume II ("Interpretation and Applications") of the Manual of Remote Sensing - Second Edition.

Having been selected by NASA officials for a one year assignment to NASA Headquarters to serve in the Resource Observation Division in NASA's Office of Space and Terrestrial Applications, completed that assignment with distinction.

S.D. DeGloria

Received California Chapter Special Recognition Award, Soil Conservation Society of America, for "his contribution in the development of remotely sensed data and dedication to the conservation of natural resources and for promoting the science and art of good land use".

Claude Johnson

Promoted to director of the Remote Sensing Research Unit on the Riverside campus.

Sharon Wall

Elected as a member of the Executive Board of the Northern California Section, American Society of Photogrammetry.

RECENT PUBLICATIONS
BY PARTICIPANTS IN THIS PROJECT

Benson, A.S. "Remote Sensing: An Aid to Managing Forest Resources" (with Andrew S. Benson) California Agriculture 33 (5) pp. 29-30 and p. 35. Illus. 1979.

Bonner, Kris G. "Mapping Riparian Habitats for the California Department of Fish and Game", (with Kris Bonner.) A report on work done under Memorandum of Understanding Between CDFG and University of California. 105 pages. Illus. 1979.

Colwell, R.N. "Remote Sensing as an Aid to the Detection of Damage to Agricultural Crops Resulting from the Operation of Coal Fired/ Electric Power Stations", an invited paper presented at the meeting of the California Energy Commission in Sacramento. 5 pages. Illus. 1979.

Colwell, R.N. "Remote Sensing of Terrain" In McGraw-Hill Encyclopedia of Science and Technology. In galley proof stage, 1 page.

Colwell, R.N. "Remote Sensing Applications in Agriculture" In McGraw-Hill Encyclopedia of Science and Technology, 2 pages. (In press).

Colwell, R.N. "Remote Sensing of Natural Resources" Chapter 6 in book entitled "Unveiling the Universe", published by COSPAR (Committee on Space Research Established by the International Council of Scientific Unions). 55 pages. Illus. (In press).

Colwell, R.N. "Remote Sensing of Natural Resources - Basic Concepts in Retrospect and Prospect" In Proceedings of IUFRO-sponsored Conference on Remote Sensing held at Moscow, Idaho, Sept. 1979. 21 pages. Illus. 1979.

Colwell, R.N. et al. "Remote Sensing Activities and Capabilities of the University of California, Berkeley Campus - A Compendium of Materials for Presentation to the Earth Observation Delegation", NASA-Johnson Spacecraft Center, Houston, Texas. November 15, 1979. UC SSL Publication, Series 20, Issue 49. 102 pages. Illus. 1979.

Colwell, R.N. "Some Historical Benchmarks in the Development of Color Aerial Photography" In Proceedings of the Seventh Biennial Workshop on Color Aerial Photography in the Plant Sciences, Davis, CA. May 15-17, 1979. 10 pages. Illus. 1979.

Colwell, R.N. "Determining the Interpretability of Various Kinds of Aerial and Space Photography" A special report presented to the twelve-man delegation of senior scientists and industrialists from the People's Republic of China on 13 October, 1979. 6 pages. Illus. 1979.

Hay, C.M. 1979. Manual Landsat Data Analysis for Crop Type Identification. Proceedings, The LACIE Symposium. NASA-Johnson Space Center Publ. #JSC-16015, Vol. II, p. 857-866.

Hay, C.M. 1979. Manual Interpretation of Landsat Data. Proceedings, The LACIE Symposium. NASA-Johnson Space Center Publ. #JSC-16015, Vol. I, p. 131-144.

Hay, C.M., R.W. Thomas, and R.N. Colwell. 1978. Advanced Analyst Interpreter Aids and Keys Development. Remote Sensing Research Program, Space Sciences Laboratory, Series 19, Issue 66 (University of California - Berkeley), 132 p.

Khorram, S. 1979. Remote Sensing Analysis of Water Quality in the San Francisco Bay and Delta. Proceedings, 13th International Symposium, Remote Sensing Environment. (Ann Arbor, Michigan) 11p.

Khorram, S. and H.G. Smith. 1979. Site-Specific Mapping of a Surface Temperature Based on NOAA-5 Satellite VHRR Data. Proceedings, Remote Sensing Earth Resources Conference. (University of Tennessee), 12 p.

Khorram, S. and H.G. Smith. 1979. Topographic Analysis of a Wildland Area Based on Digital Terrain Data. Proceedings, ACSM Annual Convention. (Washington, D.C.) 14 p.

Khorram, S. and H.G. Smith. 1979. Use of Landsat and Environmental Satellite Data in Evapotranspiration Estimation from a Wildland Area. Proceedings, 13th International Symposium, Remote Sensing Environment. (Ann Arbor, Michigan), 9 p.

Thomas, R.W., C.M. Hay, and J.C. Claydon. 1979. Development of Partitioning as an Aid to Spectral Signature Extension. Proceedings, The LACIE Symposium. NASA-Johnson Space Center Publ. #JSC-16015, Vol. II, P. 739-758.

Thomas, R.W. and S.D. DeGloria. 1979. Large-Scale Aerial Photography as a Sample Stage for Wildland Resource Inventories. Proceedings, 7th Biennial Workshop on Color Aerial Photography (University of California - Davis), 19 p.

Travlos, A.J. 1979. Multiplexed Memory: An Approach to Multi-Sensor and Multi-Temporal Data Display. Proceedings, 23rd International Technical Symposium and Instrument Display, Society of Photo-Optical Instruments Engineers (SPIE), 5 p.

Wall, S.L., R.W. Thomas, and L. Tinney. 1979. Landsat-Based Multiphase Estimation of California's Irrigated Lands. Proceedings, ASP-ACSM Fall Convention, p. 221-230.

Wensel, L.C., S.J. Titus, and R.W. Thomas. 1979. Sample Allocation in Multi-Resources Inventories. Proceedings, Society of American Foresters Workshop on Forest Resource Inventories. Colorado State University, Fort Collins.

Bowden, Leonard. 1979. "The Development of Present Dryland Farming Systems". Chapter Two in a book entitled "Agriculture in Semi-Arid Environments", Springer Verlag, Berlin.

RECENT REMOTE SENSING-RELATED THESES WRITTEN BY OUR UNIVERSITY OF CALIFORNIA PERSONNEL

A large number of students, both graduate and undergraduate, have participated in the research projects reported herein. The impact of this participation has been mutually beneficial to the students and the projects. In addition to financial support during their education, the students have been involved in applied remote sensing research and experienced the very real issues and problems associated with the demonstration and transfer of a new technology. In many instances the student's involvements have led to either Ph.D. or Master's Thesis topics directly related and of substantial value to the projects. Some of these completed and ongoing Master's Theses are briefly summarized here.

A. At the Ph.D. level:

Daus, Stephen. "A User Sensitive Clustering Algorithm for Use with Landsat Multispectral Scanner (MSS) Digital Data in Remote Sensing Aided Inventories of Natural Resources." Ph.D. in Ecology, U.C. Davis. 1979.

Lee, Clement C. "Statistical Investigation of the Propogation of Random and Non-Random Errors in Block Adjustment Systems." Ph.D. in Civil Engineering. 1979.

Malingreau, Jean P. "Landsat as an Aid to Rice Mapping in Indonesia." Ph.D. in Ecology (Dissertation in Progress; degree to be awarded in 1980).

B. At the Master's level:

"Green Fuel Moisture Estimation Using Landsat", by Susan G. Atwater, June 1979.

"Cotton Mapping from Landsat Imagery," by Tara Lee Torburn, June 1979.

"Watershed Runoff Predictions Using Landsat Digital Data," by Frederick C. Mertz, June 1979.

"Dry Farmed Small Grains in the Montezuma and Dunnigan Hills of California--A Landsat-Based Inventory, 1972-1976." by Cathy Brown, M.A. in Geography, Hayward State University. 1979.

"Cirque Characteristics and Their Influence on the Maintenance of Glaciers; -- Sierra Nevada", by Donald Chambers. M.S. in Geology, June 1979.